

FLORA W. PATTERSON.

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AGRICULTURAL EXPERIMENT STATION

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**BLACK ROT, LEAF SPOT, AND CANKER OF
POMACEOUS FRUITS**

L. R. HESLER



ITHACA, NEW YORK
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BLACK ROT, LEAF SPOT, AND CANKER OF POMACEOUS FRUITS¹

L. R. HESLER

HOST CONSIDERATIONS

PLANTS CONCERNED

The black rot, leaf spot, and canker of pomaceous fruits is primarily a disease of the apple, *Pyrus Malus* L. It affects other trees also, however, especially the pear (*Pyrus communis* L.), the quince (*Cydonia vulgaris* Pers.), and the crab (*Pyrus coronaria* L.), showing on these hosts symptoms similar to those on the apple. In addition the pathogene infests the dead parts of a great variety of other trees and shrubs, but in such cases there is usually no evidence that it has been the causal factor in the death of the tissues. In the State of New York, at least, this disease is of economic importance only on apple trees.

VARIETAL SUSCEPTIBILITY

OF FRUIT TO BLACK ROT

The summer varieties of apples are affected by black rot at the time of ripening, while winter varieties commonly suffer in storage. In Connecticut black rot is a most troublesome storage rot (Clinton, 1915:5).²

OF FOLIAGE TO LEAF SPOT

Brooks and DeMeritt (1912:183), in New Hampshire, note striking differences in the varietal resistance of apple seedlings to leaf spot. In Virginia, Ben Davis and Black Twig are more severely attacked than are other varieties (Reed, Cooley, and Rogers, 1912:5). Salmon (1907), writing from England, states that among the varieties most affected there are Peasgood, Nonsuch, Cox's Orange, and others. The writer has noted that Chenango, Baldwin, Rhode Island, and Twenty Ounce show spotted foliage more commonly in New York than do other varieties.

OF LIMBS TO CANKER

Varieties of apples exhibit a marked difference in susceptibility to the disease, and this variation is not the same with respect to the different parts affected. In western New York Twenty Ounce is the variety most severely affected by the canker. This variety is rarely found unaffected by canker, even in orchards that are managed according to improved methods. Neglected trees of the Twenty Ounce variety are often killed.

¹ Also presented to the Faculty of the Graduate School of Cornell University, May, 1914, as a major thesis in partial fulfillment of the requirements for the degree of doctor of philosophy.

² Dates in parenthesis refer to bibliography, page 126.

Paddock (1899 b:181) says that certain growers in New York State have noted that Twenty Ounce is most likely to be attacked. He lists other varieties in order of their susceptibility, as follows: Baldwin, Wagener, Rhode Island, Tompkins King. Regarding the Esopus, Paddock (1899 b:180) says that this variety has apparently run out because of this disease. In Ontario, Ben Davis, Northern Spy, and other varieties are severely injured by the disease (McCready, 1910).

THE DISEASE

NAMES

The disease on the fruit is called *black rot*, *ring rot*, *blossom-end rot*, and *brown rot*. The first name is descriptive and definite, and seems desirable.

Lesions on the foliage are termed *leaf spot*, *brown spot*, and *frog-eye*.

The names *apple canker*, *black rot canker*, and *New York apple tree canker*, are most commonly applied to the disease when it occurs on the bark. The term *apple canker* needs some qualification, since many kinds of cankers occur on the apple. It was under such an exigency that Paddock (1899 b:180, footnote) first used the name *New York apple tree canker*. The writer prefers to use this name regardless of its length, not alone because of priority, but also because of general usage.

HISTORY

THE BLACK ROT OF THE FRUIT

The disease on the fruit was observed by Peck (1879:20) in Schoharie County, New York, and he quotes the remark of stagecoach passengers that they "never before knew of apples rotting on the tree." Arthur (1885) records black rot of quince fruit at Geneva, New York, and notes the importance and infectious nature of the disease. Scribner (1890) notes the disease in New Jersey and describes the symptoms and causal nature. The same year Baccarini (1890), in Italy, observed the rotting of otherwise sound apples, pears, and peaches, the decay occurring in a storeroom of fruit gathered when ripe; this was a new appearance of the disease in that country. Two years later Halsted (1892) discussed the black rot of quince in New Jersey. Sturgis (1893, a and b) notes the disease on quinces in Connecticut in August, 1892, and later (1894) confirms the work of Halsted. Kinney (1895 c) figures and describes the disease in Rhode Island. In the same year it became an object of control measures in Kentucky (Garman, 1895). Black rot of apple is reported by Burrill and Blair (1901) in Illinois; they give a careful description of the disease and distinguish it from other apple rots. The following year Clinton (1902), writing from the same station, remarks that the disease on

apples had attracted attention for several years, and that it was known to have occurred in Illinois at least as early as 1879. The disease as a storage rot was studied by Lamson (1902) in New Hampshire the same year. Faurot (1912) describes the disease in Missouri.

W.A. Orton (1904, 1905, 1906, 1907) publishes records of the black rot of pome fruits, the reports having come to him chiefly from the Middle West. In 1905 the black rot of quince and pear was especially injurious in Ohio. Evans (1910) called the attention of the apple growers of South Africa to the disease, which had just been found on apples at Grahamstown and also in a consignment of apples from Sidney, Australia. He urged the importance of excluding the disease from the Transvaal. Recent studies on black rot have been reported by Wolf (1913) in Alabama.

THE LEAF SPOT

The earliest record which the writer has found concerning the leaf spot is that by Alwood (1892), who reports brown spot of apple foliage in Virginia. He had noticed it for several years but states that it was not serious until 1891, when an outbreak occurred over the State. Kinney (1895 b) describes the disease in Rhode Island on apple and pear leaves, and says that it was very common in that State in 1895. Stewart (1896) reports having found the disease on Long Island in May, 1895; he notes that it had been observed in 1894 at Westbury, Long Island, by Professor Beach. Lamson (1899) lists the disease from New Hampshire and reports it as having done serious damage in some cases. Corbett (1900) reports "brown spot," or "frog-eye," as common throughout the southern and eastern counties of West Virginia, and as being more injurious than either blight or scab. Stewart and Eustace (1902) studied the cause and control of leaf spot in the eastern United States. The same year Clinton (1902) notes the severity of the disease in Illinois, and later (Clinton, 1904) he reports its common occurrence in Connecticut. Stone and Smith (1903) record it as one of the most noticeable diseases of the season of 1902 in Massachusetts. Scott and Quaintance (1907) report the spotting of apple foliage in the Ozark region, and in the following year there appeared a more extensive work on the leaf spot problem by Scott and Rorer (1908). Work on the leaf spot was begun in New Hampshire in 1908 by I. M. Lewis (1908); this investigation was carried further by Brooks and DeMeritt (1912), who report it in full. Recent work on the leaf spot form of this disease has been published in Virginia by Crabill (1915).

THE CANKER FORM

According to Paddock (1899 b:180), orchardists have been familiar with this canker disease for years. Attention was first called to the

injury by Waite (1898 a), in a paper read at the meeting of the Western New York Horticultural Society in 1898. In the spring of 1898, Paddock (1898, a and b, and 1899 a) began investigations which extended through two seasons. He records having noticed the disease as early as 1891, and says that it became important about 1895. In 1897, according to Paddock (1899 b:192), considerable "twig blight" was found at Odessa, New York.

Mangin (1901) reports the disease in France on branches of apples, describing its symptoms in order, as he says, to put horticulturists on guard against invasion of the country by the pathogene. The same year Chester (1901, a and b), in Delaware, observed what he believed to be the same disease on apples and pears. His attention had been called to the canker on the latter host in the spring of 1900, near Smyrna. His illustrations suggest the possibility that the disease was the superficial bark canker of Edgerton (1908). A few years later Lochhead (1905) described the disease in Canada. Clinton (1907), writing from Connecticut, states that his attention was called to a peculiar disease of apple limbs in the spring of 1906.

Another record of the disease which has appeared from France is that by Griffon and Maublanc (1910). They note very serious injury to pears in that country, and assert that at the national school of agriculture the disease was first known in 1908. A study of the disease was taken up in Canada by Bethune (1909). He reports a great amount of damage from cankers in the region east of Toronto. The following year a synopsis of the investigations in the province of Ontario was published by McCready (1910). A point of interest noted in this paper is that the great freeze of 1903-1904 in Prince Edward County marked the beginning of the canker epiphytotic there. The disease has received further attention in France by Arnaud (1912), who lists it as occurring on a number of different plants.

GEOGRAPHICAL OCCURRENCE

The disease has a very general distribution throughout the temperate regions of the globe. Heretofore it has been regarded as a disease peculiar to eastern and middle western America, but it is now apparent that its limit is no longer to be so regarded. It has been found in Canada, particularly in Ontario (Bethune, 1909), Quebec (Lochhead, 1905 and 1909), and Nova Scotia (Plant Pathology Herb., Cornell University Exsicc. no. 2657, and Güssow, letter to the writer). It occurs in Europe from Italy to England, according to the observations of Shear (1913:81-82). From England Berkeley (1836) reports it on apple fruit, while Salmon (1907) found it on apple foliage. It is unknown in Norway (Schöyén, letter to the writer), while both Ravn and Lind (letters) state that it

is not present in Denmark. From Russia the disease has been reported by Potebnia (1907 and 1910). Jaczewsky (letter to the writer) states that the black rot and canker forms occur in the provinces of Kharkof and Tchernigof, and in the Transcaucasian and Turkestan regions. Potebnia (letter) has collected all the forms in Kursk, near the city of Fatej, and states it as his opinion that the disease occurs generally throughout Russia. Bubák (1909) reports it from Austria-Hungary. It probably occurs in Switzerland, Germany, and Holland, according to the general statement of Shear (1913:82). Kirchner (1906:440) lists it from Germany. It may not be prevalent there, however, for Hollrung (letter) says the disease is not well known in Sachsen. Its occurrence in France is reported by Arnaud (1912) and others. The black rot form has been collected in the vicinity of Brussels, Belgium, by Bommer and Rousseau (1885). Some years ago it was introduced into Cape Colony from New South Wales (Evans, 1910:62, footnote).

So far as the writer has been able to ascertain, the disease is widely distributed in America. It does not occur, however, so far as indicated by results from a circular letter sent to the plant pathologists of the state agricultural experiment stations, in the following States: Arizona, Colorado, Florida, Idaho, Louisiana, Montana, Nevada, North Dakota, South Dakota, Tennessee, Utah, Washington, Wyoming, and possibly Oregon. The canker form is commonest in the East, especially in New York, while fruit rot seems to occur more frequently in the New England and Middle Atlantic sections, although Wilson (1913) reports its occurrence throughout North America east of the Rocky Mountains. In the Middle Western States, particularly Ohio and Indiana, the pear and quince, as well as the apple, appear to have suffered considerably. Quaintance and Scott (1912) state that the leaf spot occurs in all sections east of the Rocky Mountains where the apple is grown. In another publication Scott (1912) asserts that it is found in all humid sections of America. According to Reed, Cooley, and Rogers (1912:3-4), "frog-eye" is widespread in Virginia. Other States in which the disease occurs are Arkansas, Connecticut, Illinois, Maryland, Massachusetts, Missouri, Nebraska, New Hampshire, New York (particularly Long Island), Rhode Island, and West Virginia (Scott and Rorer, 1908:48-49).

Probably no apple disease except apple scab is commoner in New York State than the one here considered. Throughout western New York the canker form is very prevalent. From replies to a circular letter sent to fruit growers in various parts of the State, it appears that this disease is more or less common and serious in all sections, except possibly in the central eastern part. The fruit and foliage rarely suffer appreciably in the State, although black rot and leaf spot are not infrequently found.

ECONOMIC IMPORTANCE

GENERAL CONSIDERATIONS

The nature of the losses caused by this disease makes very difficult the possibility of an estimate concerning them. So far as the writer has found, no reliable data are at hand in regard to this point. The combined injuries produced by the canker, the black rot, and the leaf spot are doubtless greater than is commonly supposed. It is undoubtedly true that the New York apple tree canker is often confused with other cankers by some growers, thus increasing the difficulty of obtaining reliable estimates on the destructiveness of this disease.

It is generally considered that canker is one of the commonest and most troublesome diseases of the apple, although its destructiveness is not uniform in different parts of the country. According to Shear (1913: 81-82), the black rot disease of apple is found in Europe from Italy to England; yet he states that noticeable injury from the disease in orchards has never been reported. On the other hand, Griffon and Maublanc (1910:308) state that in France the injury may be very serious. In contrast to the general situation in Europe, it may be noted that the damage done by this disease in America is great.

NATURE OF LOSSES

INJURY TO FRUIT. Whenever pome fruits are attacked they are rendered worthless so far as their market value is concerned. The extent of injury may be small while the fruit still hangs on the tree, but ultimately in storage complete destruction is likely to result. Brooks (1909) states that in New Hampshire the black rot is very common and does considerable damage in cellar storage. Burrill and Blair (1901:2) report "great loss at times" in Illinois, and Clinton (1902), in the same State, compares the importance of bitter rot and black rot of apple. The latter he regards as likely to occur in every orchard to some extent. In Kentucky, black rot of apples is regarded as the commonest of fruit rots, according to Garman (1895:127). Stone (letter to the writer) estimates that in Massachusetts from eighty to ninety per cent of fruit rots is black rot. Evans (1910) reports a case in which rotting and mummified pome fruits appeared in a shipment to Cape Colony, and states in this regard:

During the past three months four hundred and ninety-eight cases of apples and pears in this condition from Cape Colony have been detained, and in order to safeguard the interests of Transvaal fruit growers, the Government, under Government Notice No. 569, of 18th June, 1908, have warned importers of fruit that all consignments of pomaceous fruits found infected with this fungus to the extent of one per cent and upwards will be destroyed upon arrival in this Colony or returned to the consignor.

There is no reason to suppose that this number by any means represents the total amount of diseased fruit that has reached the Transvaal, to say nothing of the other parts of South Africa.

INJURY TO FOLIAGE. The damage to foliage depends on the extent of the infection. In the milder cases the injury is not appreciable. In the more severe cases, partial or even complete defoliation may occur from six weeks to two months before the ripening of the fruit, as a result of which the fruit either drops from the tree or remains small and is of poor quality. In such cases the fruit buds are so weakened as to decrease the possibility of a crop the following year, and the vitality of the trees is impaired. Alwood (1892:62) estimates a loss of seventy-five per cent of the foliage in a part of an old orchard in Virginia, while Stewart (1896) reports a case of complete defoliation of some trees on Long Island by the first of July. It is interesting to note, for comparison, that in 1900, in West Virginia, the disease was regarded by Corbett (1900) as more injurious to foliage than either blight or scab. Scott and Rorer (1909:10-11) have observed a case in which, as they believe, the pathogene causing this disease assisted in the killing, in late summer, of a large proportion of the fruit buds of the apple. They state that on Winesaps it would seem the pathogene alone is capable of killing the buds. Further investigation is deemed desirable by these writers.

INJURY TO LIMBS. As a rule the canker is confined to the orchard, although Wilson (1913) says that young nursery stock may be killed. Bethune (1909:28-29) reports that cankers cause a great amount of damage in Ontario, Canada. J. W. Eastham (letter to the writer), of the Ontario Experiment Farm, states that this is the most prevalent canker in the region east of Toronto, and according to Brooks (1909) it is the commonest canker in New Hampshire. Warren and McCourt (1905:341) refer to this form of the disease as causing more loss in Wayne County, New York, than any other disease except scab. They report it as very serious in fourteen per cent of the orchards, and as doing considerable damage in nineteen per cent of them. In Niagara County, New York, Cummings (1909:304) found canker affecting the orchards as follows: slightly, sixty-one orchards; considerably, sixty-three; seriously, thirty-seven. Paddock (1899b:181, 188) cites a case in which, in an apple orchard of 80 acres, the trees on 30 acres were ruined and had been taken out; the trees on the remaining 50 acres were then of little value.

In one apple orchard of three hundred and fifty trees under the writer's observation, a count made in August, 1913, showed about thirty-three per cent of the trees (Baldwin, Hubbardston, and Northern Spy varieties) with from one to three dead limbs each. On examination of the dead limbs the New York apple tree canker was found to be present on all. It was further observed that the pathogene causing the infection had lived over winter and had spread to such an extent that girdling had resulted and the foliage had turned yellow and wilted. The fruit on such limbs

soon shriveled and was lost. A careful count showed that approximately ten or twelve barrels of fruit were rendered worthless. The loss here might be placed at approximately twenty to twenty-five dollars, or about seven cents a tree. According to the United States Census for 1910, there were in New York, on the 168,667 farms reporting, 11,248,203 apple trees of bearing age.³ On this basis, assuming the losses in the above-mentioned orchard to be an average, the apparent annual loss would be about three-fourths of a million dollars for a single season in New York State. Many cases can be cited in which the infection by New York apple tree canker is very much more severe, while few orchards in the State, regardless of their careful management, are entirely free from the disease.

Epiphytotics of this disease, such as have recently been experienced in the case of the chestnut blight, are of rare or unknown occurrence. It is characteristic of the disease to take a constant toll year after year, like the cereal smuts. To the losses so incurred must be added the cost of growing diseased limbs. In many cases these limbs die, resulting in the cost of their removal and destruction, which possibly does not seem great in a given year but is not negligible in the aggregate.

SYMPTOMS

ON THE FRUIT

The disease on the fruit is primarily a ripe rot, but it may appear several weeks before maturity of the fruit. It may begin anywhere on the surface or at the blossom end. Frequently the lesions are centered about an injury such as that caused by insects or hail (Plate VII, 1).

Usually there is only one spot on a fruit. The skin at first becomes brown in a small area, but later darkens, finally turning black. On green fruit the affected part may turn black before enlarging to any great extent, whereas on fruit that is ripe or ripening, the whole may be involved before it darkens appreciably. Often concentric bands of uniform breadth and of slightly different shades of color appear about the center of the lesion. The affected area is distinct from the healthy part, and the diseased tissues are not of unpleasant taste as in many fruit decays. Later stages in the development of the rot show a shriveled and much wrinkled surface, which typically becomes covered with black pustules (Plate VII, 2). These characters may be assumed within a month or in less time. Ultimately a dry mummy is produced, which may hang to the tree for a year or more.

Black rot has been confused with brown rot and bitter rot, and even with soft rot. The brown rot disease produces a smooth, coal black, and shiny mummy, which is much less wrinkled than the black rot mummy. Bitter rot, in addition to its unpleasant taste, often shows pinkish specks in a

³ Bureau of the Census. Thirteenth Census of the United States taken in the year 1910, 7:195. 1913.

localized region near the center of the lesion. The softening of the pulp in soft rot is not characteristic of black rot specimens. Perhaps the most distinctive characters of black rot are the long duration of the plumpness and juiciness of the tissues, and the occurrence of the above-mentioned black pustules. Under certain conditions the surface of the apple fruit also becomes studded with white tufts; but these are not commonly found and are not to be regarded as a diagnostic symptom.

Fruits of the pear and the quince affected with black rot finally become dry and hard. In storage the peach becomes waxy when affected with the disease, according to Baccarini (1890:67).

ON THE LEAVES

The foliage of the apple is more frequently attacked than that of the pear and the quince. The spots usually appear about the time the leaves open. Alwood (1892:62) notes this date as being about May 1 in Virginia. He records a second attack which becomes evident about June 20, and a third outbreak the last of July. Brooks and DeMeritt (1912:181) state that in New Hampshire apple leaf spot appears soon after the leaves unfold from the bud. In western New York spotting is more commonly apparent in July and August. The writer observed spots developed in September, 1913, at Byron, New York.

The number of lesions that may appear on a single leaf varies from one to several, and these may be scattered or localized on the surface (Plate VII, 3). The first evidence of a spot is a minute purple speck, which soon enlarges until it has reached a diameter of from two to ten millimeters, averaging about four millimeters. The purplish color is maintained for a considerable time, during which the margin is somewhat indefinite. Later the lesion is of a yellowish brown color and the spot assumes a more or less circular shape, while the margin becomes more definite. Still later the margin becomes elevated and the diseased area sunken. As the spots grow older they become lobed, due to a secondary extension of the pathogene from one or more points, and finally a series of more or less concentric areas produces an irregular blotch in which the outline of the original spot can be recognized. The center has now become grayish brown, and the entire lesion presents an appearance which has given rise to the name *frog-eye*.

The spots on the lower surface seem to enlarge as rapidly as those on the upper, but they are not so conspicuous. Sometimes the center of the spot on the lower surface is grayish brown. The whole diseased area may, however, merely appear dark and indefinite.

Frequently small, black, dome-like bodies are found on the upper surface of the leaf, usually toward the center of the lesion. In severe cases the

leaves turn yellow and fall from the tree. According to Brooks and DeMeritt (1912:181), this leaf fall occurs from six to eight weeks earlier than would happen normally. Reed, Cooley, and Rogers (1912:3) maintain that defoliation may occur early enough for a new crop of leaves to be put forth the same season. Trees robbed of their foliage from year to year must eventually become greatly reduced in vitality and finally succumb to a premature death.

Bordeaux injury is sometimes very similar to frog-eye leaf spot; Brooks and DeMeritt (1912:190) state that this is especially true if rains follow the application. Kinney (1895 b) notes also that injuries from the leaf miner (*Tischeria malifoliella* Clemens) are sometimes mistaken for leaf spot.

ON THE LIMBS

In western New York, young spots may be found on the bark at any time from the last of April until toward the close of the growing season. Numerous young cankers have been observed on Twenty Ounce trees in Monroe County orchards during the month of August. It is the rule that the larger limbs are much more susceptible than the twigs, and the trunks show comparatively few lesions. The cankers on the trunks occur more or less uniformly on the southwest side of trees. The limbs more commonly show the diseased spots on the upper side. Lesions are very often found about the base of a small limb or about a wound in the bark.

In the earlier stages of the formation of a canker, the bark is slightly sunken (Plates VIII, and IX, 4) and reddish brown in color. The diseased area slowly increases in size and darkens, and, although not conspicuous at a distance, the spot is readily distinguished from healthy tissue on closer examination. Some lesions remain very small, measuring only a few centimeters in their longer diameter; in such cases the canker usually dies out at the end of the year. Where the injury is larger, the diseased spot enlarges from year to year for a distance of a meter or even more.

It is often observed that a canker is merely a superficial roughening of the bark. In other cases the bark is killed to the wood and becomes conspicuously cracked (Plate x).

The discolored area may extend over a considerable surface; or, regardless of its size, a crevice may appear at the margin, limiting, temporarily at least, the extent of the lesion. Further spread of the pathogene results in the formation of a prominent spot, which soon forms a second line of demarcation between the healthy and the diseased tissue. Repetition of this process from one or more points at the margin occurs, thus producing a lobed appearance (Plate XI, 2); or the spreading may arise from

all points about the first marginal crack, so that a series of concentric crevices is developed, as described for frog-eye of the leaves. The bark remains closely appressed to the wood for at least a year; later the dead bark cracks and falls away, exposing the wood and a callus around the margin of the wound (Plate x, 3).

Cankers that begin to form early in the season show numerous fruiting pustules of the pathogene scattered over the central area of the spot. These may not become evident, however, until the second season.

Large limbs are rarely girdled the first year; the girdling comes about by the enlargement of the canker the following season. Complete encircling results in the death of the parts above the canker, as evidenced by the yellowing and dropping of the leaves (Plate XII, 1) and the shriveling of bark and fruit. It is not uncommon in such cases to find the fruit clinging to the twigs for a year or more.

Clinton (1907) describes a peculiar type of lesion on apple limbs. He says, in part:

Another and more peculiar feature of the trouble was the enlargement of the limbs into somewhat fusiform swellings, as shown in the illustration. In some cases several of the swellings followed one another on the same limb. These enlargements generally showed a greater swelling on one side than on the opposite, and often the bark was split down the more swollen side. Cross and longitudinal sections showed that the swellings were apparently the result of severe cold, which had injured the limbs unevenly along the branch, as shown by the blackened wood on the injured portion.

Delacroix (1903a:135) notes a thickening at the base of some cankers. This he finds to be a sort of cushion developed in a transverse direction in the healthy bark. The writer has occasionally observed cankers showing hypertrophy at the upper and lower ends of the diseased part (Plate x, 4).

It is to be noted that on quince twigs the cankers are often very indefinite. A rare specimen is shown in Plate x, 5. The normal color of the bark is not distinctly lighter than that of the diseased part, so that on this host the disease doubtless passes unnoticed in many cases.

OTHER ORGANS AFFECTED

A unique case in Virginia of fall blossoming of the apple following the canker has been described by Reed (1908). This author found normal blossoms on an apple tree in the orchards of the Virginia Experiment Station on October 5. The cankers on the limbs had caused the death of more than half the top of the tree, and many branches, severely affected, had been able to make a very small amount of growth during the season. Reed says: "It was on such branches as these that fruit buds were found open on the above named date. Examination of the blossoms showed that they were normal as regards parts, color, and internal relationships.

I am informed by Professor H. L. Price of the Department of Horticulture of this Experiment Station that this fall blossoming is not uncommon on trees which are badly affected by the black rot fungus."

ETIOLOGY

The pathogene here concerned is the fungus *Physalospora Cydoniae* Arnaud.

MORPHOLOGY

PERITHECIA. The perithecia have been found by the writer on the twigs of apple (*Pyrus malus* L.) and of witch-hazel (*Hamamelis virginiana* L.), and have been described by him in another publication

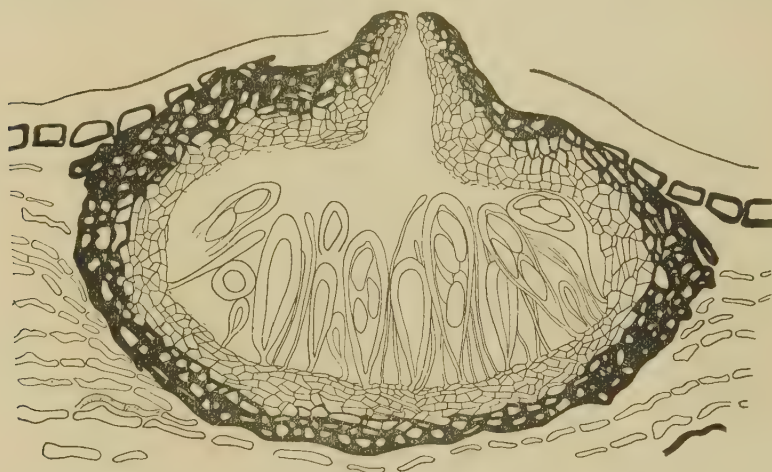


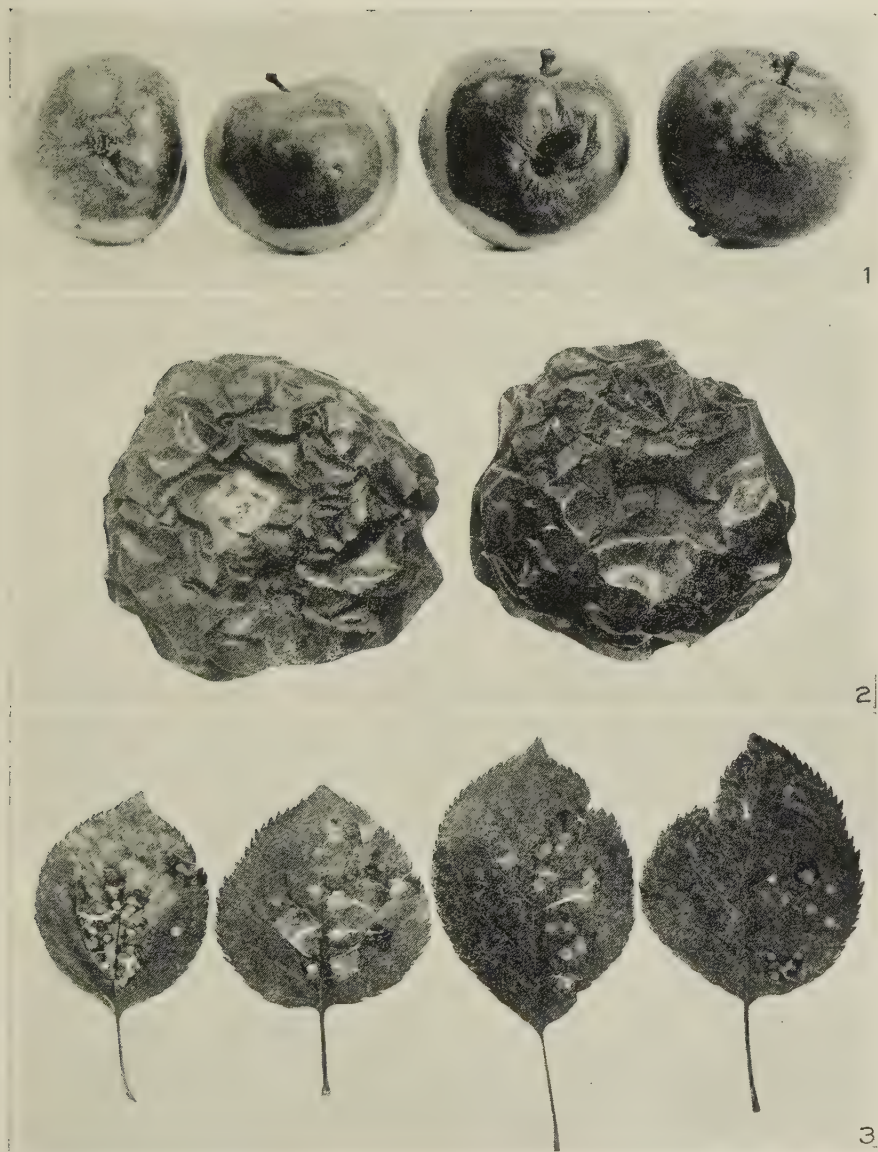
FIG. 18. PERITHECIUM OF *PHYSALOSPORA CYDONIAE*

Camera lucida drawing of a median longisection of a typical perithecium

(Hesler, 1913:293). Recently the writer has found the ascogenous form on twigs of white oak (*Quercus alba* L.).

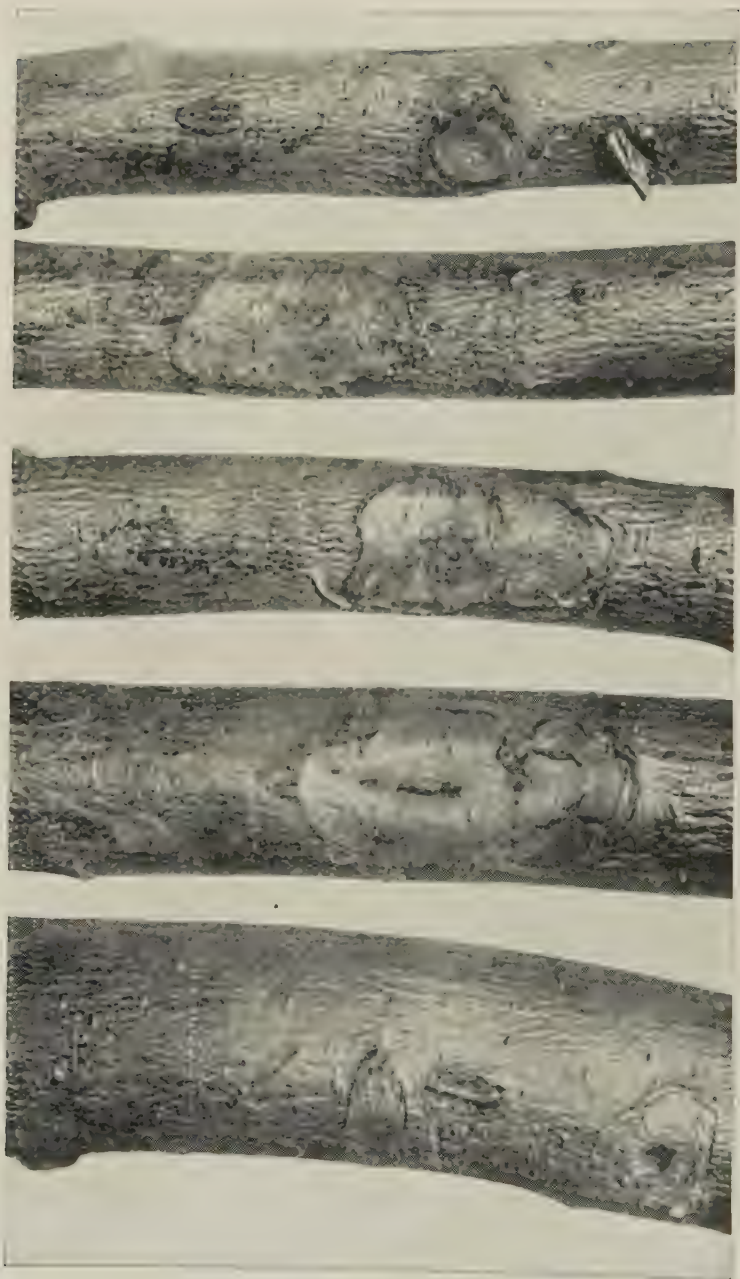
The perithecia are usually scattered, standing separate from one another. Sometimes, however, from two to four fruit bodies are joined together, but no stroma has ever been observed. They are buried in the cortical tissues, protruding at maturity by a short, papillate ostiole. Their form is globose to subglobose, measuring from 180 to 324 μ in the vertical diameter by 300 to 400 μ in the horizontal diameter, averaging about 225 by 325 μ .

A typical perithecium is shown in figure 18. The wall is differentiated into two layers. The thickness of the outer layer varies slightly with the sides and base of the perithecium, and the pseudo-cells are thick-



SYMPTOMS OF THE DISEASE ON FRUIT AND FOLIAGE

1. Types of infection on apples, early stages
2. Apples reduced to mummies as a result of the disease
3. Types of infection on apple leaves as commonly found in New York State



INOCULATION EXPERIMENTS ON APPLE

The specimen on the left is a check; the rest show the effects of inoculation with *Erwinia amylovora* (Yarrow) (1913). The specimen on the right was taken from a branch from which the disease had been removed. Date of inoculation, July 15, 1913. (See also Bulletin 379, p. 20, 1913.)



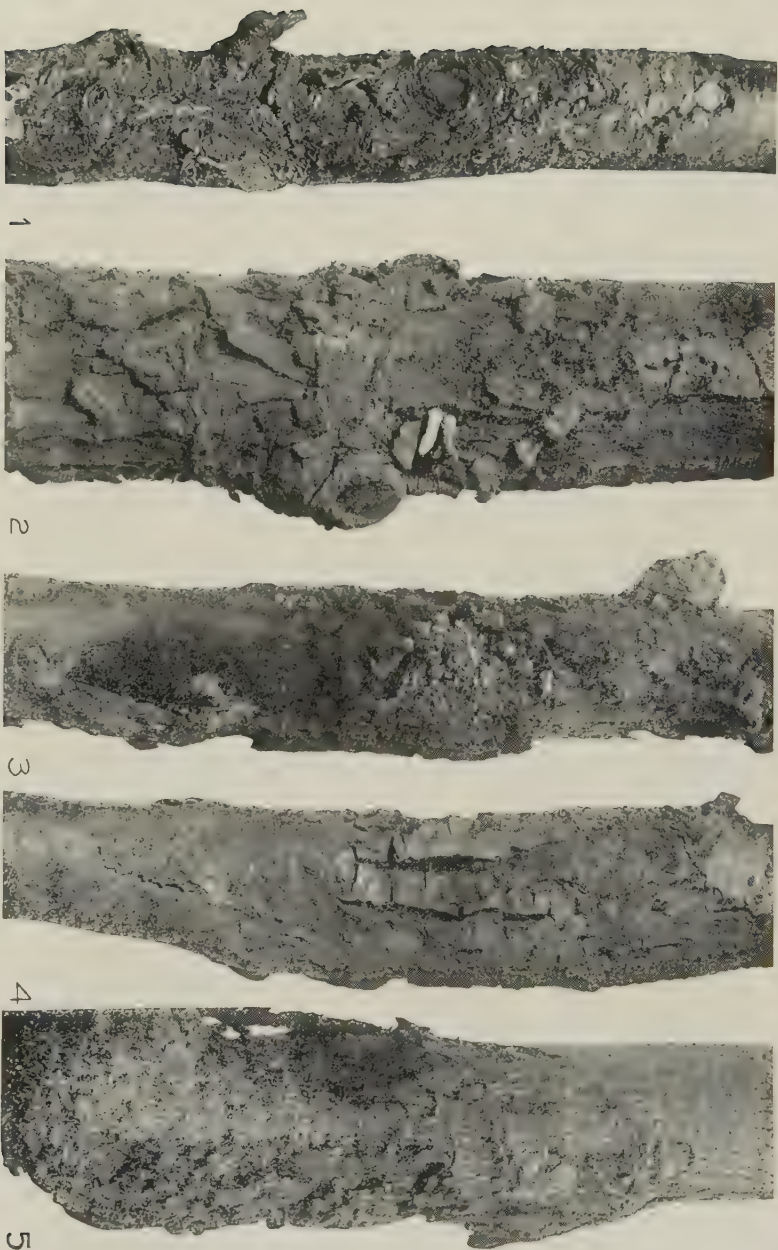
NATURAL CANKERS AND CANKERS PRODUCED BY ARTIFICIAL INOCULATION WITH
PHYSALOSPORA CYDONIAE

1. Natural infection on the left; artificial infection on the right. The latter inoculated on July 1, 1913, with a strain from Twenty Ounce apple bark. Photograph made September 30, 1913

2. Canker on trunk of mature pear tree. Inoculation made July 18, 1910, photograph made September 1, 1911

3. The result of inoculation by use of pycnosporos from apple leaves. The healing process has occluded the wound before the pathogene could produce a large canker. Inoculation made July 1, 1912, photograph made September 20, 1913

4. Canker on Baldwin twig produced artificially, using ascospores from apple. Inoculation made July 25, 1914, photograph made December 10, 1914



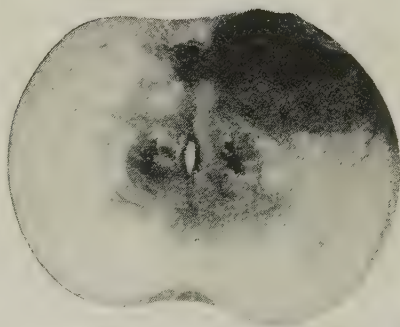
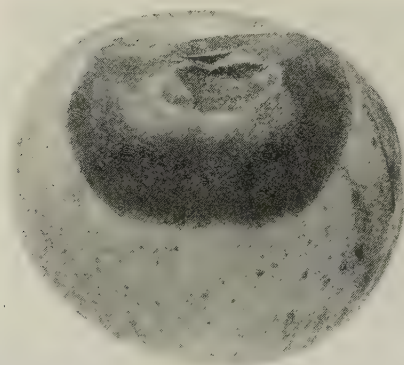
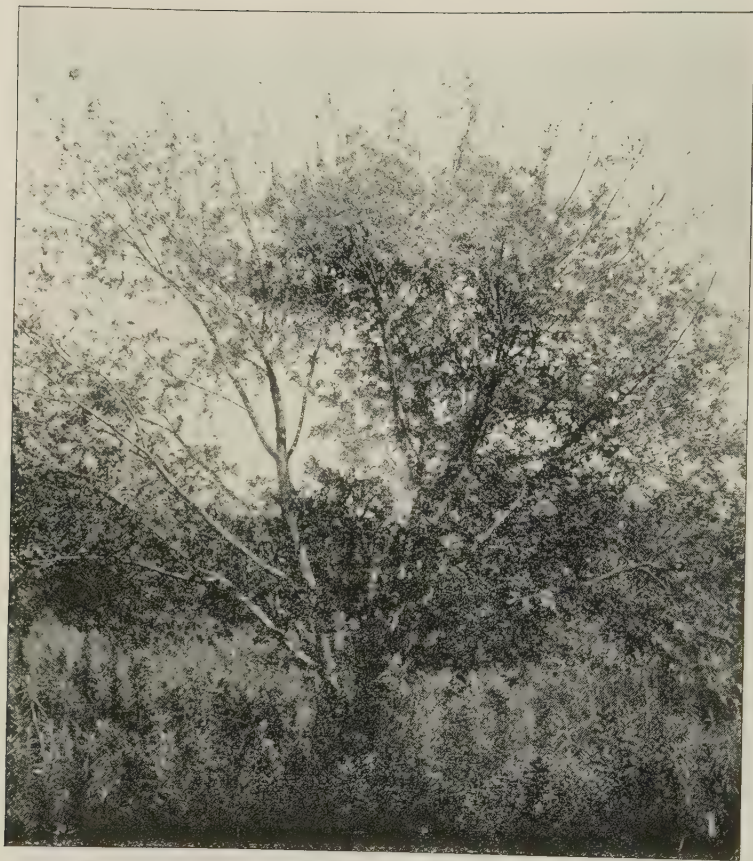
SYMPTOMS OF THE NEW YORK APPLE TREE CANKER

1. Typical old and much-roughened canker on Twenty Ounce apple. The bark is still clinging
2. Old canker on apple, showing roughened surface. Some of the bark has fallen from the lesion
3. Old canker on apple, showing callus about the margin. Note that most of the bark has sloughed off
4. Cankered limb of apple, showing hypertrophy toward the upper end of the lesion
5. Canker on quince



INOCULATION EXPERIMENTS WITH *PHYSALOSPORA CYDONIAE*

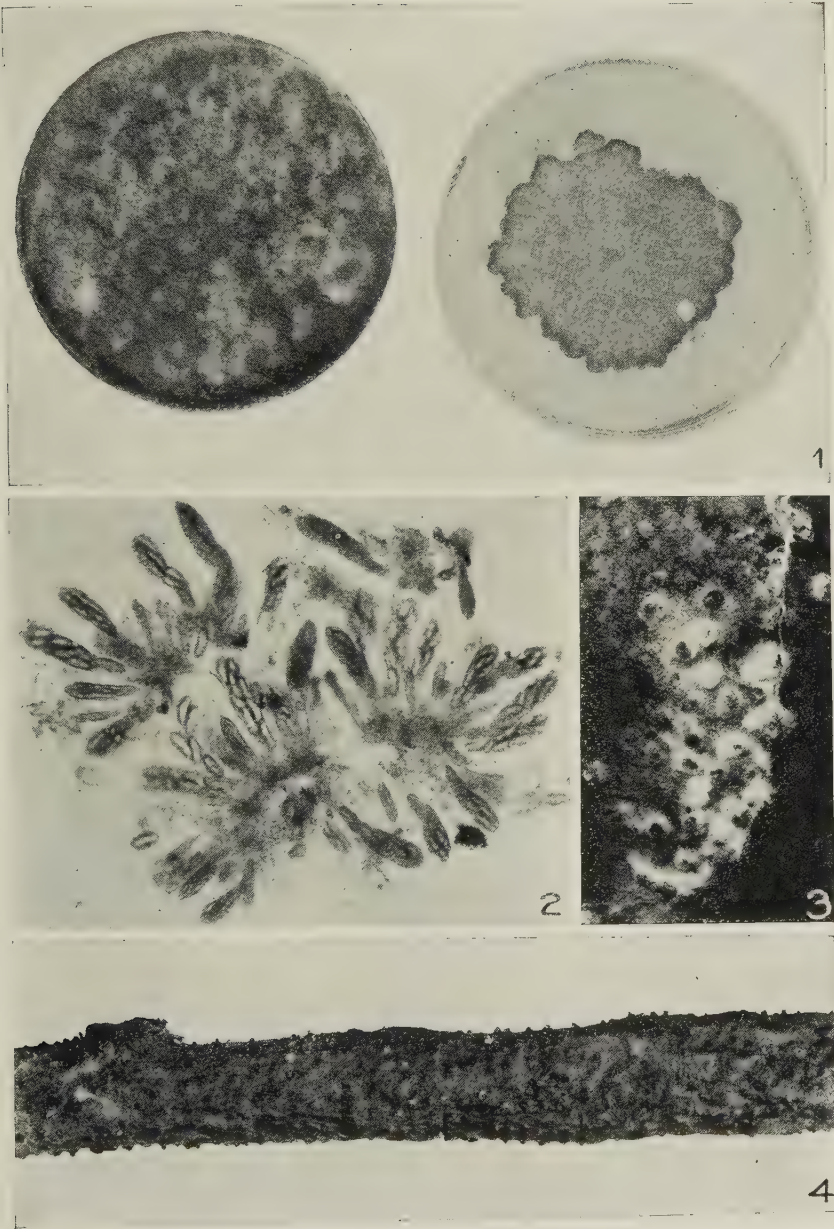
1. The three cankers on the left produced by inoculating pear with ascospores from apple. Check on the right. Inoculations made June 6, 1913, photograph made September 20, 1913.
2. Canker on Twenty Ounce limb produced artificially, using pycnospores from apple. Inoculation made June 20, 1912, photograph made September 20, 1913.
3. Canker produced on pear by inoculation with ascospores from apple. The presence of pycnidia should be noted. Inoculation made June 6, 1913, photograph made September 20, 1913.



2

NEW YORK APPLE TREE CANKER

1. Twenty Ounce apple tree, some of the larger limbs of which have been girdled by the fungus. Evidence that this has occurred is found in the defoliated tops of affected limbs
2. External view at left, and internal view at right, of young black rot lesions on apple; the specimen on the right shows the tissues involved

VARIOUS STAGES OF *PHYSALOSPORA CYDONIAE*

1. Showing differences in growth on nutrient agar from pycnospores (heavy dark growth on left) and from ascospores (scant growth on right)
2. Photomicrograph of asci, ascospores, and paraphyses from a single perithecium
3. Sclerotia as they appear in pure culture
4. Twig of apple, showing dark masses of pycnospores which have oozed from the pycnidia when the twig was kept in a moist chamber



INOCULATION EXPERIMENTS WITH *PHYSALOSPORA CYDONIÆ*

1. Canker on right, check on left. Inoculation made July 1, 1912, using pycnospores from pear, the fungus having followed fire blight. Photograph made September 20, 1913
2. Comparison of two different apple strains on pear. Specimen shown on left inoculated with ascospores from apple. Specimen shown in center inoculated with pycnospores from apple, following fire blight. The very slight infection should be noted. Check on right. Inoculation made June 6, 1913, photograph made September 20, 1913

walled. The inner, thin-walled layer is of very uniform diameter. In cases in which the perithecium is depressed, the outer layer is reduced at the base and is from one to three pseudo-cells in thickness, whereas the lateral outer walls are from two to five layers of pseudo-cells in thickness. The ostiole appears as a narrow passage in the papilla, the walls of which show the same distinct layers as those just described for the sides and base of the perithecium.

The asci, with the interspersed paraphyses, usually fill the cavity of the perithecium. Arnaud (1912:11) states that in general the paraphyses are formed by rows of cells which

in the mature perithecium are separated one from another in the form of distinct filaments.

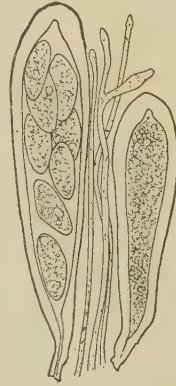


FIG. 19. ASCI AND PARAPHYSES OF *PHYSALOSPORA CYDONIAE*

Camera lucida drawing of asci and paraphyses, showing structure of the latter and typical arrangement of ascospores in the ascus

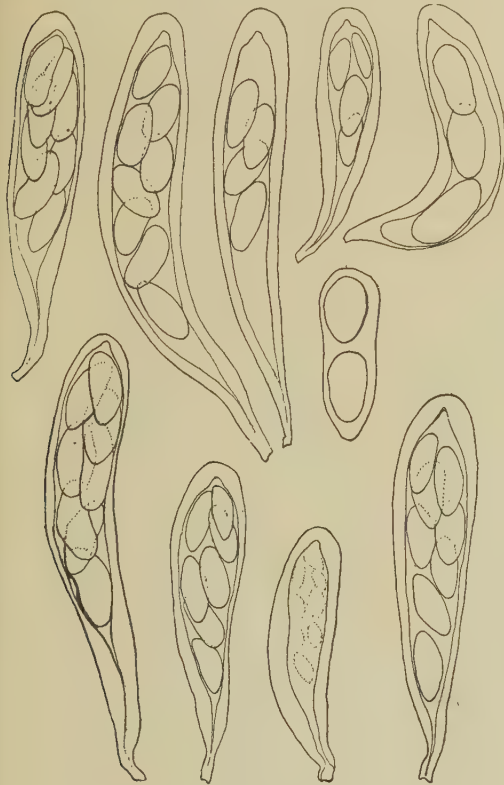


FIG. 20. ASCI OF *PHYSALOSPORA CYDONIAE* FROM DIFFERENT HOSTS

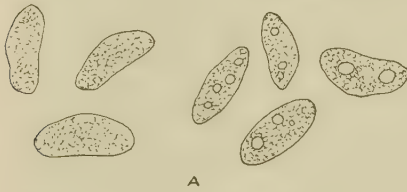
The upper series represents variations as found on apple bark. The lower series shows variations from bark of witch-hazel

He says that in certain cases, however, the paraphyses remain agglutinated by their walls and appear in section like rows of cellular cavities, as in *Cucurbitaria* (*C. Spartii* and other species). He explains that if the rows of cells are not very numerous the existence of the paraphyses may become uncertain. Arnaud finds this the case, with *Physalospora Cydoniae*. The writer, however, has not observed this condition of the paraphyses; to him they appear distinct and non-septate (Fig. 19).

The asci are abundant;

asci crushed from one perithecium are shown in Plate XIII, 2. They are usually clavate, although they sometimes tend to be cylindrical, measuring

from 21 to $32\ \mu$ by 130 to $180\ \mu$. The tip of the ascus is thickened, but a complete canal from the inner wall to the outside has not been observed;



only a suggestion of such a canal has been seen even after the perithecia had been kept in a moist chamber for several hours. Variations of asci from different hosts are shown in figure 20.



FIG. 21. TYPES OF ASCOSPORES OF *PHY-SALOSPORA CYDONIAE*

A, Typical mature ascospores as found in nature; B, ascospores, showing stages in the development of the gelatinous sheath; C, old ascospores, showing peculiar contents

The ascospores are ellipsoidal, or often inequilateral (Fig. 21); they measure from 10.8 to $15.2\ \mu$ by 23.4 to $34.2\ \mu$, averaging 11.5 by $28\ \mu$. They are hyaline to greenish yellow. Under ordinary conditions the spores show a very thin gelatinous sheath, but after they have been in a saturated atmosphere for a few hours the sheath becomes very broad and evident. The arrangement of the spores in the ascus is more or less biseriate. The paraphyses are distinct and are occasionally branched near the tip.

Not infrequently the apex shows a tendency to be clavate.

The number of spores in each ascus is typically eight, but exceptions have been found in the fungus on apple twigs. The variation ranges from two to eight spores within an ascus, all intervening numbers having been observed. Four-spored asci are not uncommon (Fig. 20). The contents of ascospores are either densely granular, or vacuolate and oily. Two guttules are occasionally found.

PYCNIDIA. The morphology of the pycnidial form of this fungus is variable (Fig. 22). The pycnidia are situated in the cortical tissues and are usually scattered and distinct, although on the same organ of the host they may be single, confluent, or united into a stroma. The number of pycnidia per unit of area is usually less on woody substrata than on fruits; on apple fruit there may be from one hundred and twenty to one hundred and fifty pycnidia per square centimeter.

The typical simple pycnidium (Fig. 22, A) measures from 200 to $300\ \mu$ in each diameter, whereas the compound fruit body may vary from 200 to $460\ \mu$ in the vertical diameter and from 200 to $720\ \mu$ in the horizontal diameter (Fig. 22, G). Their shape is in general the same as that of the perithecia, globose to subglobose, and they have the same distinct outer and inner walls. The thickness of the entire pycnidial wall is variable,

as in the case of the perithecium. The basal part is thinner in the case of the subglobose fruit bodies. This condition may be attributed to the fact that less protection is needed at the base; or perhaps here the thickness may be partially determined by mechanical pressure brought about by the resistance offered by the host tissue.

Arising from the inner thin-walled cells are the pycnosporophores, which

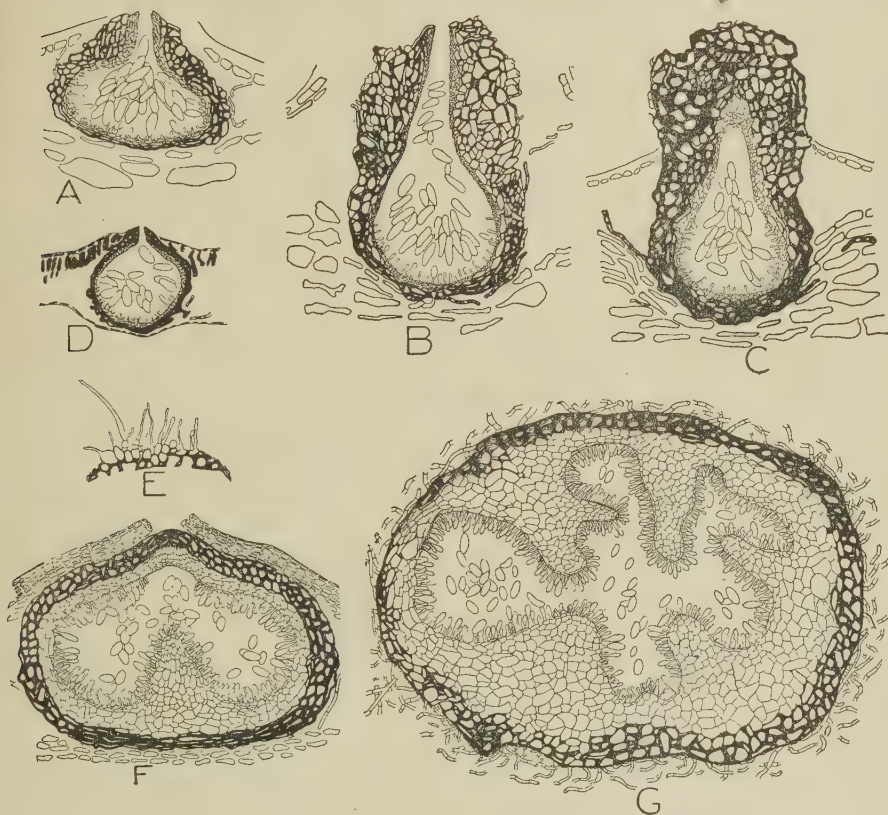


FIG. 22. VARIATIONS OF PYCNIDIA OF *PHYSALOSPORA CYDONIAE*

A, Typical simple unilocular pycnidium; B, pycnidium with long neck, similar to C but with an ostiolum; C, pycnidium similar to B, ostiolum not yet developed; D, pycnidium from apple leaf; E, hair-like outgrowths on the tip of an ostiolum, developed under moist conditions; F, pycnidium with mound-like structure at base; G, pycnidium which approaches in appearance the fruiting body of species belonging to the form-genus *Botryodiplodia*

extend entad. They are clavate, flask-shaped, or cylindrical. They may be as long as the spore itself, from 25 to 30 μ , or may measure less than 8 μ ; the average dimensions are from 10 to 15 μ by 3 to 4 μ . At the tip of each is developed a pycnospore.

In some cases there is a mound-like structure at the base of the pycnidium (Fig. 22, F). This is illustrated by Duggar (1909:353, fig. 171). It has been a matter of conjecture whether this may appear only in an oblique tan-

gential section, or whether it is a bilocular tendency. It does not seem possible that any such structure would appear merely in a section that was not cut vertically. If this were true, the question would then arise as to whether this same appearance would not extend at all points along the lining of the cavity, and hence merely make the wall thicker rather than give it the aspect just described. It seems, therefore, to be a bilocular tendency.

Frequently the pycnidium approaches and even reaches the condition characteristic of the form-genus *Botryodiplodia* (Fig. 22, c). The sporogenous layer extends inward at places, giving the inner wall a corrugated appearance. This condition is found in nature and has been developed in culture from spores in pycnidia which originally did not show this structure. The simplest condition suggesting the form-genus *Botryodiplodia* is found when a single mound-like structure occurs at the base of the pycnidium, as previously described (Fig. 22, f). Frequently this finds its expression in the form of a bilocular condition, which is a step nearer the *Botryodiplodia* type.

The ostiolum offers some interesting variations. Miss Walker (1908) describes a form which she believes lacks an ostiolum. In the place of the typical conical ostiolate neck there was found a much-thickened wall at the apex of the fruiting body, and the papilla itself appeared longer than usual. The writer has cultured the ostiolate form from an apple, and has obtained, on various agars and on apple fruit, pycnidia having the characteristics described by Miss Walker (Fig. 22, c). The evidence at hand indicates that a pore may or may not be present, depending somewhat on the time of year and on weather conditions. In any case an ostiolum will ultimately be developed (Fig. 22, A, B, D). Brooks and De Meritt (1912:184) report three types of pycnidia but all forms are ostiolate. It does not seem likely that any strain will remain void of an ostiolum throughout its history. A strongly papillate form similar to that shown in figure 22, c, but with an ostiole developed, is illustrated in figure 22, D. A form of the fungus which at first appeared to have a non-erumpent pycnidium was found in apple bark and twigs of *Celastrus scandens* L. After the material had been in a moist chamber for a few days, however, the pycnidia broke through the epidermis.

In conclusion it may be stated that the pycnidia may vary in morphology on different host plants, yet this variation is no greater than that on the same host plant.

PYCNIDIAL FORMATION. The pycnidia arise from the mycelium and are found abundantly on cankers and decayed fruit. Also they may be produced on various artificial media. They occur sparingly on spotted leaves.

So far as has been determined, the process of formation is similar on different substrata. The earlier stages are more accurately followed in agar cultures than on any organs of the host plant. The writer's observations have been made by examining petri-dish cultures under the low power of the microscope and by the use of prepared slides from such cultures. The material was prepared as follows: Pycnosporos or hyphal threads were planted in the center of agar plates, and, as the hyphæ developed, pycnidia appeared in more or less definite concentric rings. In this way the oldest pycnidia were nearest the starting point, whereas the youngest were found near the margin of the culture, the stages between

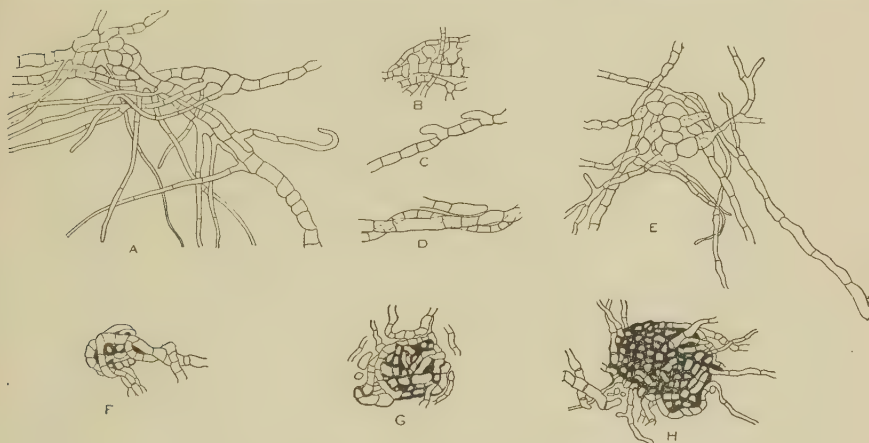


FIG. 23. DEVELOPMENTAL STAGES OF THE PYCNIDIUM

A, Early stage in pycnidial development. The hyphæ have become closely septate, are broadened, and are beginning to tangle. B, Early stage in the process, showing the origin of hyphæ which enter into the pycnidium. Some come from adjacent hyphæ, others arise from cells of the threads in the immediate tangle. C, Early stage. Branching of hypha, preliminary to coiling and twisting as in D and F. D, Early stage. Twisting of hyphæ about one another. E, Early stage, showing symphyogenetic and meristematic tendencies in pycnidial formation. F, G, H, More advanced stages in the process of pycnidial formation

the two being intermediate. Blocks of agar were cut out from the dish, fixed, and imbedded in paraffin. A single section frequently includes a gradual series of the several stages, from the very youngest to the more mature structures. The sections were made both perpendicular and parallel to the surface of the agar, the second method proving the more satisfactory.

The young pycnidium as it occurs in agar appears to be made up of a closely tangled mass of hyphæ. In section the young fruiting body is composed of pseudoparenchyma, the cells of which are closely packed and consequently somewhat angular (Fig. 23, H). As is noted by De Bary (1887:247), pycnidia may arise either as intercalary formations on hyphal branches by the swelling and division of cells, or by the union and inter-

weaving of mycelial threads. The former process is termed meristogenetic and the latter symphyogenetic. A third possible method, not unknown among the fungi, is by a combination of these two processes.

Potebnia (1910:62), in a note on *Sphaeropsis pseudodiplodia* (Fckl.) G. Del., states that the pycnidia arise meristogenetically. The writer was for some time under the impression that this was the character of the process, but this opinion was based on observations of later stages rather than on the earliest steps in the development. The dense pseudoparenchyma of the maturer fruit bodies suggests meristematic divisions, but apparently the structure, for the most part, arises symphyogenetically (Fig. 23).

In agar cultures a group of threads may be observed to be directed toward a common point where the pycnidium is to be formed. Here the hyphæ are composed of cells from 6 to 7 μ broad, their length varying from 20 to 70 μ , always longer than broad. In the region where the pycnidium is to be developed, the cells become noticeably shorter by the laying down of new walls; the cells also increase in diameter by growth, and the hyphæ increase their numbers by branching (Fig. 23, A). This stage is observed with ease in petri-dish cultures.

The behavior of the threads in the formation of the pseudoparenchyma is varied and the process is somewhat indefinite. The mycelial branches that enter into the structure may arise from the short cells (Fig. 23, A), or they may grow in from adjacent hyphæ (Fig. 23, E). The interspaces found in the earlier stages are filled by the growing in of these branches and by a budding-like action of the hyphal cells bordering the space (Fig. 23, B).

Serial sections show that there is considerable coiling and gnarling of hyphæ. Threads may twist about one another for some distance in a rope-like fashion (Fig. 23, D). In some cases the threads are localized in their intertwining so that the resulting structure becomes a knot or ball of densely woven hyphæ (Fig. 23, F, G, H). The formation of such a structure necessitates that the hyphæ pass into many planes, and in cross sections the ends of many hyphæ present a pseudoparenchymatous appearance (Fig. 23, H).

In the intertwining process, hyphæ may conjugate in an H-shaped fashion. In some cases threads that are parallel probably fuse side by side, although the evidence for this is not complete.

The next important stage is the formation of the cavity. At first no differentiation of the closely tangled mass of threads is shown in the young pycnidium, but soon the preparation for the cavity is evident. Certain cells occupying the central region become more densely granular than the surrounding cells. This appears to be the beginning of the

cavity. Later stages show the breaking down of these cells, and finally an oval or a globose cavity is formed. Baccharini (1890:69) states that these central cells transform by a mucilaginous process, and that the cavity is enlarged by the gelatinous center's absorbing water and exerting a pressure on the sporogenous layer. He emphasizes the importance of the central "tissue" and expresses the opinion that it has a special function, believing that it is destined to become sporogenous whereas the outer surrounding cortex only furnishes nourishment to these cells.

The formation of the ostiole is similar to the process exhibited by the development of the cavity. The cells break down, enlarging the passage, and finally the wall is definite and continuous with that of the spore cavity.

The spore-bearing area occupies almost all the space not included by the ostiole. The cells lining the cavity arch outward, and continued growth results in the formation of a stalk. The tip of the stalk swells, and ultimately a mature spore is cut off (Fig. 24). The further development of the pycnospores has been discussed.

PYCNOSPORES. The morphology of the pycnospores has been more carefully studied than that of the pycnidia. In the same and in different pycnidia on the same and on different plants, wide variation with respect to size, color, shape, and septation have been observed (Fig. 25).

The average mature pycnospore measures about 12 by 25 μ , although the range in single or in different pycnidia on the same or on different hosts or host parts may be considerable. From the measurement of hundreds of pycnospores, it has been found that they range from 7 to 16.2 μ broad by from 16 to 36 μ long, while the averages from different hosts range from 9.5 to 13.3 μ by 19.8 to 27.8 μ . Spores on the apple show a slight variation on the different organs, as follows: on the fruit, 10.6 by 25 μ ; on the twigs, 11.6 by 23.8 μ ; on large limbs, 12.9 by 24.9 μ ; on the foliage, 12.3 by 23.5 μ . Paddock (1899b:195, table 1) notes considerable variability with respect to size as the spores occur on different plants, but he says: "Yet the spores produced on apple fruits inoculated with cultures from either host, are of the same size and character; similarly, though not shown in the table, when pear trees are inoculated with cultures of *Sphaeropsis* taken from apple trees the resulting pycnidia and spores are of the average size of those found in nature on pear tree bark."

The mature pycnospores are brownish, varying from a very light to a dark ferruginous color. The color darkens with age, so that the very youngest mature spores are hyaline. The question of the maturity of



FIG. 24. PYCNOSPORE DEVELOPMENT

Stages in the formation of a pycnospore from a conidiophore

these colorless spores has frequently arisen. The writer has germinated them, and is of the opinion that they should be regarded as physiologically mature. The hyaline color is replaced later by a yellowish green tinge, and finally a brown of varying density is assumed, the spore becoming very dark brown in the final condition of coloration, as noted above.



FIG. 25. VARIATIONS AND TYPES OF PYCNOSPORA OF *PHYSALOSPORA CYDONIAE* FROM VARIOUS HOSTS

A, Typical unicellular pycnosporangia; B, typical bicellular pycnosporangia; C, three- and four-celled pycnosporangia, not common; D, pycnosporangia from apple twig; E, pycnosporangia from apple limb; F, pycnosporangia from a single pycnidium, from apple twig; G, very old pycnosporangia which have burst; H, pycnosporangia from apple fruit; I, pycnosporangia from sumac; J, pycnosporangia from sumac showing peculiar fusion; K, pycnosporangia from sumac; L, pycnosporangia from crab; M, pycnosporangia from mulberry; N, pycnosporangia from rose fruits; O, pycnosporangia from bittersweet; P, pycnosporangia from rose of Sharon; Q, pycnosporangia from witch-hazel; R, pycnosporangia from spicebush

The several shades of color may be represented by the spores of a single pycnidium, although the majority are uniform in this respect.

The typical pycnosporangium is ellipsoidal, frequently tapering slightly toward the basal end (Fig. 25, A). The shape also is a variable character, however. Pyriform spores may accompany ellipsoidal, globose, or somewhat elongated forms.

The question of septation of pycnosporos is of importance because of the fact that it involves the systematic value of the character, or variation if it be so called, in separating the form-genera *Sphaeropsis* and *Diplodia*, and because of the physiological significance of its formation. In nature, three possible conditions exist with respect to the presence of one- and two-celled spores. A pycnidium may contain only one-celled spores (Fig. 25, A) or only two-celled forms (Fig. 25, B), or both kinds may be present (Fig. 25, E, F, G, R). Occasionally three-celled and even four-celled pycnosporos have been observed (Fig. 25, C). It is a striking feature in this regard that no strain has come under the writer's observation that will not produce two-celled spores. Just what factors induce cross-wall formation is a matter not well understood. Mature unicellular spores placed to germinate, whether germinating at once or not, will sometimes develop a septum. Again, spores that are found scattered about on the bark of the host plant show the bicellular condition. In very dark spores the cross-wall is not always readily visible and may be easily overlooked.

The writer made observations on several strains regarding this character. Spores were placed in a drop of water and set in a moist chamber for several hours. At the beginning and at the end of each experiment the spores were examined for septation. The strains when collected, with the exception of one (no. 64)⁴ on mulberry (*Morus alba* L.), possessed one-celled spores only. After being placed to germinate, or in nature after they had oozed forth on the substratum, septa began to appear and the percentages were as follows: one-celled spores, from two to ninety-five per cent; two-celled spores, from five to ninety-eight per cent; three- and four-celled forms, rare. The average for all such observations shows that the percentage of one- and two-celled forms is about equal.

Cultural studies were made of an apple strain (no. 82) with reference to this and other morphological characters. A single ellipsoidal, brown, one-celled pycnosporos, 10.8 by 21 μ in size, from a pycnidium in which all the spores were one-celled and typically like the one described, was isolated on March 3, 1913, and a pure culture was developed from it. Examination of the culture at intervals showed the development of hyaline, *Macrophoma*-like spores. At the end of twenty-four days these had become brownish, and, while the majority were ellipsoidal, averaging from 9 to 10 μ by 21 to 22 μ , a few were pyriform and measured 12.6 by 30.6 μ . At the end of fifty days an occasional spore was found with a cross-wall; after eighty days thirty per cent of the spores were two-celled, and on May 27 sixty per cent were bicellular.

From the same culture a second generation was originated by culturing a one-celled, ellipsoidal, brown spore, 11 by 22 μ in size. The following

⁴ The specimens were numbered consecutively regardless of source, host, and other considerations.

notes were taken: Within two weeks an occasional spore measured 7.5 by $21\ \mu$, although the usual size was from 9 to $10.8\ \mu$ by 19.8 to $26.1\ \mu$. After forty days several two-celled spores appeared. At the end of two months, fifty per cent of the spores were one-septate.

A third generation was initiated by planting a spore from the second generation, of the same shape and measurement as the preceding. After one month twenty-five per cent of the pycnospores were of the *Diplodia* type.

Another series was studied, using a two-celled spore from a pycnidium in which both one-celled and two-celled forms were present. Within one generation a single spore, 10.8 by $21\ \mu$ in size, two-celled, brown, ellipsoidal, had developed offspring showing the usual color variations — that is, from hyaline to greenish, and finally brownish. After eighteen days some of the spores measured 12 by $28\ \mu$, the average being 10.5 by $21\ \mu$. Septation began to show after five weeks, and within eighty days sixty per cent of the spores examined were two-celled.

Apparently, from a single pycnidium in which the spores are of a given type there may develop in succeeding generations a wide variation in size, color, shape, and septation. In an early stage the *Macrophoma* type may appear in both size and color; later the *Eu-Sphaeropsis* type, one-celled, brown; and finally the *Diplodia* forms. The variable shapes that may be found in the generations succeeding a given type indicate that two-celled forms may be mere deviations in the life cycle. On the other hand, Brooks and DeMeritt (1912:184) report from New Hampshire a large-spored form which holds true to its morphological characteristics for several generations.

Markings on the wall of the pycnospores are reported by Griffon and Maublanc (1910:312). These authors claim to have discovered an undescribed character of the spores of this species, namely, a shagreened wall. This character is not reported elsewhere in literature, and has not been observed by the writer among the several strains studied, including Dr. Peck's type specimens of *Sphaeropsis Malorum* Peck.⁵

Long, slender bodies, measuring about $1.5\ \mu$ in diameter and often $50\ \mu$ in length, have been observed interspersed between the pycnospores of a strain from apple twigs. They are not of frequent occurrence in the experience of the writer.

MYCELIUM. The mycelium is composed of septate tubes, monopodially branched and comparatively broad — being on an average about 4 to $7\ \mu$ in diameter. In the young hyphæ cross-walls are rare, but in older branches the threads are often short and frequently with bulging lateral

⁵ Following the Vienna Code published in 1906 (Wettstein, R. von, Wiesner, J., and Zahlbruckner, A., Verhandlungen des Internationalen Botanischen Kongresses in Wien, 1905, p. 200), this specific name should be capitalized.

walls. Color is lacking in young aërial threads, but as age increases a greenish yellow, then bluish green, brown, and finally dark brown, hue is assumed. In mass the mycelium appears black. In cultures lacking potassium a violet tinge has been observed. The walls of the hyphæ are relatively thick, and sometimes a decided double contour of the membrane is visible. The appearance of the cell contents

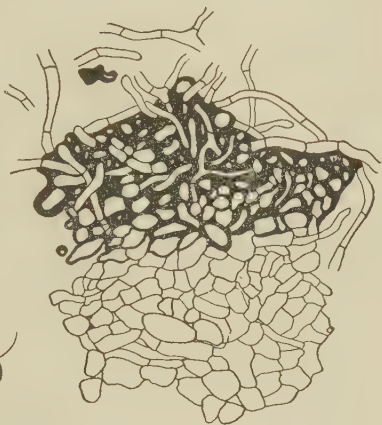


FIG. 26. PART OF CROSS SECTION OF SCLEROTIUM

varies, apparently depending somewhat on age and nutrition. Young and well-nourished cells are densely granular, while older threads contain vacuoles and glycogen drops in abundance.

SCLEROTIA (Plate XIII, 3, and Fig. 26). Sclerotial bodies have been found in nutrient media of high sugar content and in oat agar cultures of ascospores from *Hamamelis virginiana*. Walker (1908:38) reports the development of sclerotium-like bodies resembling pycnidia on artificial media. They have also been observed by Baccarini (1890:67) just under the skin of the apple.

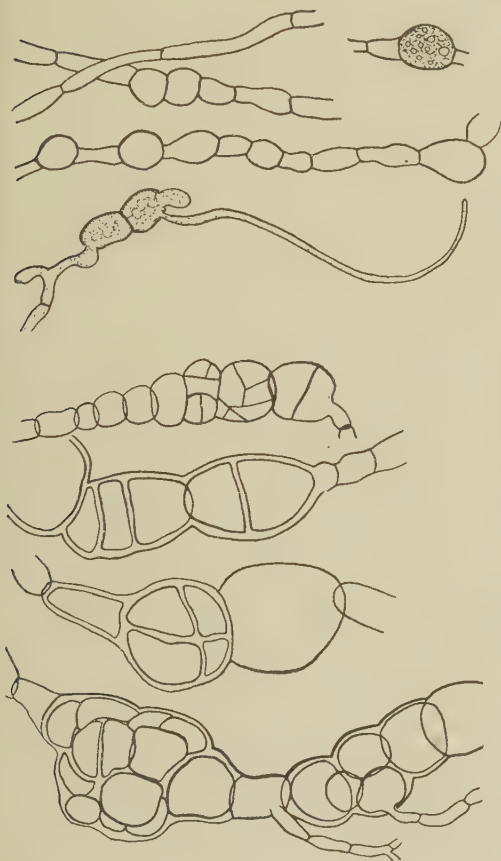


FIG. 27. CHLAMYDOSPORES OF *PHYSALOSPORA CYDONIAE*

Types of chlamydospores found in pure cultures

CHLAMYDOSPORES (Fig. 27). Chlamydospores have doubtfully been observed by the writer in host tissues. In a few cases a suggestion of

such a body was found in apple bark. In old cultures on various artificial media, large, thick-walled, intercalary, brown, spore-like bodies are sometimes present in abundance. They were also obtained easily by transferring bits of mycelium to sterile water. They have been observed in agar cultures that have become contaminated by bacteria, being found more especially near the bacterial colonies. The most striking forms observed were on old agar cultures of the strain (no. 6) from *Rhus typhina* L. Similar bodies are described and figured by Hedges and Tenny (1912:16) in their studies on *Sphaeropsis tumefaciens*. These large bodies suggest young pycnidia, owing to the form and cellular structure. All gradations from thick-walled, colorless, greenish or brownish, granular, swollen cells, occurring singly or in chains, are very common in artificial culture. These bodies have been germinated by the writer, the germ tubes developing into hyphae of the usual type (Fig. 27, near top).

MICROCONIDIA (Fig. 28). Microconidia, or secondary bud-like bodies, have been observed in culture after forty-eight hours. They develop as swellings near the tips of the growing hyphae. They are globose or somewhat pyriform, measuring from 3.6 to 6.3 μ by 7 to 14.5 μ , averaging 4 by 9.5 μ .



FIG. 28. MICROCONIDIA OF *PHYSALOSPORIA CYDONIAE*. Showing microconidia developed on the mycelial threads. The three microconidia in the center are magnified 800 diameters.

YEAST FORMS. Alwood (1898 b) records the discovery of a yeast form occurring in the laboratory cultures of the fungus, which on isolation and reinoculation of apple fruit produced its fruiting bodies. Such forms have never occurred in any of the writer's pure cultures.

The variations exhibited by this fungus do not represent unique phenomena among the fungi. Shear and Wood (1913:63) say of *Glomerella*: "No character, either morphological or physiological, seems to be well fixed." They find (page 64 of same reference) wide variability in the manner of conidial production; all intergradations between a hyphomycetous type and a distinct melanconiacious type of structure occur in cultures. Setae may be present in some cultures and absent in others, while paraphyses are regarded as of little taxonomic value. Duggar (1909:303), in speaking of the *Alternaria-Macrosporium* question, says: "The catenulate method of spore production has been reported only in artificial cultures in this case, and it is possible, furthermore, to obtain for various fungi in such cultures in general many variations from what would be considered the normal type of spore production upon the host." It is stated in the same place that cultures of such forms as *Fusarium*, *Gloeosporium*, and *Cercospora* yield variable characters in culture. Seaver (1908) points out the misleading

and misused color characters in some of the Hypocreales. Stevens and Hall (1909b) report considerable variation in certain forms under different environmental influences.

PHYSIOLOGY

METHODS OF ISOLATION. The chief methods used in isolating the organism were: the plating of spores in agar and the transfer of single germinating spores; transfer of single spores by the capillary tube method as described previously by the writer (1913:291-292); planting bits of diseased tissue in agar plates. The first two methods are advantageous in getting pure lines or races. The third method has practical advantages in its simplicity and the ease with which the culture is obtained.

CULTURAL CHARACTERS — GENERAL. The ability of this fungus to grow on the commonly used culture media is a noticeable physiological character. It is easily isolated, and its appearance in successive stages of development is generally the same in all the culture media employed. The colonies are at first cottony; after from two to five days the submerged threads are green or blue-green for about a week, after which the growth is dark or nearly black, but almost without exception the outer ends of the aerial threads maintain their original cottony appearance. After from seven to ten days pycnidia appear. The writer has always been able to develop pycnidia in culture, although Brooks and DeMeritt (1912:183) found considerable difficulty in getting cultures to sporulate. Often a distinct concentric zonation occurs in plate and tube cultures. The exudation in culture of drops of liquid has been observed frequently. This is described by Potebnia (1907), who regards it as an excretion product.

The general characters described above — except zonation, which is irregular in its occurrence — apply to the following media: several different agars, including potato, prune, apple, oat, bean, and nutrient; solid vegetable substances, such as potato cylinders, bean pods, apple twigs, and apple fruit cylinders; synthetic liquid media, such as Fraenkel and Voge's, Cohn's, Rankin's, and Uschinsky's solutions.

CULTURAL CHARACTERS — SPECIAL. The writer (1913:292-293) has previously reported differences in the growth of cultures from ascospores and pycnospores when planted in +10 nutrient agar. On the one hand pycnospores were developed within about one week from pycnospore plantings, whereas on the other hand no fruiting bodies had appeared after several weeks in cultures from ascospores, the growth remaining stunted. Cultures of ascospores and of pycnospores were similar on other media (Plate XIII, 1).

PROTOPLASMIC STREAMING. Protoplasmic streaming in the hyphæ has been studied by Potebnia (1907). He has found that movement

begins with the germination of the pycnospore. The direction is first toward the tip, some granules moving more rapidly than others. On reaching the tip, those that have moved the faster direct their movement backward, in some cases forming groups. The streaming is not dependent either on evaporation through aerial parts or on the structure of the protoplasm, but is conditioned only by apical growth of the hyphæ and by inner processes. The slow movement is pulsative, and it is observed that increased temperature accelerates forward movement and cooling often induces backward flow. It is suggested that the streaming is similar to the slow movement observed by Van Tieghem in the hyphæ of the Mucorales.

PATHOGENICITY

The ability of the organism to produce the disease, particularly the leaf spot and canker forms, has been a matter of no little consideration. The difficulties that are met in attempting to infect various plants have brought out, not only some conflicting results, but also, what is more encouraging, some interesting problems with reference to the causal agent and the taxonomic relationship of the so-called species on the different host plants. The cross-infection of the several hosts, and the rôle of organisms associated with *Physalospora Cydoniæ* in the production of the lesions, are points that have a practical and scientific bearing on the whole problem. The different forms of the disease are followed in the succeeding discussion.

BLACK ROT OF APPLE. The ability of the fungus to cause decay of fruits was established, after a fashion, in 1878 by Peck, who writes (1879:20) that "the disease is contagious, and may be communicated from one apple to another."

Von Thümen (1879)⁶ regards the fungus, which he called *Diplodia Malorum* Fckl., as a saprophyte rather than a parasite, but believes that it is capable of attacking sound fruit and is able to cause notable injury in storage.

Arthur (1885) inoculated sound quinces by inserting beneath the skin a bit of diseased fruit tissue containing spores of the fungus (which he calls *Sphaeropsis Cydoniæ* C. & E.). The inoculated fruits were placed under a bell jar. Arthur says: "The spores germinated, and the rotting progressed slowly, when, on the twenty-second day, the spot had reached an inch and a half in diameter, and the fruiting points had begun to appear."

Halsted (1892) states that the fungus grows interchangeably on apple, quince, and pear fruits. He reports having corroborated his laboratory experiments by field observations.

⁶ Original not seen by the writer; context taken from Baccarini (1890:70).

Sturgis (1894) made inoculations both in the field and in the laboratory, confirming the work of Halsted (1892) and showing that when the skin was not broken previous to inoculation the fruits remained in a sound condition.

Paddock (1899 b:185) produced black rot of apple artificially within a few hours by the use of the black-spored fungus, pycnidia appearing after sixteen days. Again, Paddock states (page 193 of same reference) that the fungus from pear, quince, and Japanese plum produces rot in apple, pear, and quince, if the skin is punctured and moisture is furnished.

More recent inoculation experiments are reported by Walker (1908), Morse (1909), Arnaud (1912), and others.

Two forms of *Sphaeropsis* were observed by Walker (1908), both of which were capable of producing black rot — the newer form, however, being a more vigorous rot producer. The morphological differences have been previously noted.

The writer made several inoculations (tables 1 and 2) on apples of different varieties, using different strains from bark and fruit. In all cases pure cultures of the fungus were used. In making wounds to serve as infection courts a flamed scalpel was employed. Material transferred from the culture consisted of mycelium and spores; this was inserted in the injury previously made, and the fruits were placed in sterile moist chambers. It is to be noted from table 1 that different strains vary in their ability to infect the same variety. Attention is called to a comparison of strains 1, 2, 3, and 4. All were used on Baldwin apples on the same date and under similar conditions, yet the results were different. Strains 1 and 3 showed slow decay, with no pycnidia after nineteen days. On the other hand, strains 2 and 4 caused rapid decay and abundant pycnidia in the same length of time.

As shown in table 1, nine different varieties were inoculated with the same culture, the results being variable with reference to decay, fruit body production, and the formation of concentric rings.

It has been commonly observed that older cultures produce the disease less readily than do younger cultures. The best results were obtained by the use of cultures not more than two months old.

LEAF SPOT OF APPLE. Various theories have been advanced to explain the cause of the leaf spot disease. In 1902 Stewart and Eustace (1902:228) believed spray injury to be the responsible agency. They further suggest (page 232 of same reference) that drops of rain act as lenses and so concentrate the rays of the sun, overheating the tissues beneath. The belief is ultimately expressed by them that the large proportion of leaf spot in New York is due to spray injury and is not of fungous origin. Frost has been considered the causal factor by Stone and Smith (1903) in

TABLE 1. RESULTS OF INOCULATIONS ON RIPE APPLE FRUIT IN THE LABORATORY, USING STRAINS OF THE FUNGUS FROM APPLE

Source and number of strain	Variety inoculated	Date of inoculation	Conditions provided	Number of fruits	Results
A-Twenty Ounce apple bark	Yellow Transparent	July 19, 1910.....	Fruits in sterile chamber. Tissue wounded. No moisture	4	100 per cent infection; pycnidia formed and fruit mummified by August 15
A-Twenty Ounce apple bark	Red Astrachan....	July 19, 1910.....		2	100 per cent infection
Apple bark, not numbered..	Oliver.....	January, 1911.....		1	100 per cent infection. Pycnidia after 16 days
Apple, not numbered.....	?	February 2, 1911..		2	100 per cent infection. Slow decay on one fruit; other fruit well decayed in 8 days
A-Twenty Ounce apple bark	Red Astrachan....	July 15, 1911.....		2	Pycnidia in 10 days
1-Apple twig.....	Baldwin.....	April 7, 1911.....		1	Slight infection after 19 days. Decay not typical. No pycnidia
2-Apple fruit.....	Baldwin.....	April 7, 1911.....		1	Pycnidia after 19 days. Decay rapid
3-Twenty Ounce apple bark.	Baldwin.....	April 7, 1911.....		1	Decay slow. No pycnidia after 19 days
4-Russet apple bark.....	Baldwin.....	April 7, 1911.....		1	Pycnidia abundant after 19 days
A-Twenty Ounce apple bark	Yellow Newtown..	January 12, 1911..		2	Decay slow; lesion 1 cm. in diameter after 18 days. No pycnidia
A-Twenty Ounce apple bark	Ben Davis.....	January 12, 1911..		2	Fruit about one-fourth decayed after 18 days. Pycnidia abundant
A-Twenty Ounce apple bark	Oliver.....	January 12, 1911..		2	Fruit about one-fourth decayed after 18 days. Pycnidia abundant
A-Twenty Ounce apple bark	Cranberry Pippin..	January 12, 1911..		2	Lesion 6 cm. in diameter after 18 days. No pycnidia

A-Twenty Ounce apple bark	Northern Spy.....	January 12, 1911..	2	Pycnidia after 16 days. Concentric rings apparent
A-Twenty Ounce apple bark	Rebel.....	January 12, 1911..	2	Apple one-fourth rotten after 18 days. Pycnidia present. Concentric rings evident
A-Twenty Ounce apple bark	Rome Beauty.....	January 12, 1911..	2	Apple one-fourth rotten after 18 days. Pycnidia present. Concentric rings evident

TABLE 2. RESULTS OF INOCULATIONS ON GREEN APPLE FRUIT IN THE LABORATORY

Source and number of strain	Variety inoculated	Date of inoculation	Conditions provided	Number of fruits	Results
A-Twenty Ounce bark.....	Yellow Transparent	July 14, 1910.....	Wound, moisture	2	Decay slow after 5 days
A-Twenty Ounce bark.....	Yellow Transparent	July 19, 1910.....	Wound, moisture	2	100 per cent infection. Fruits taken from tree, inoculated in laboratory
82-Apple bark.....	Twenty Ounce....	July 16, 1913.....	Wound, moisture	4	Slight decay after 1 week. Whole fruit involved after 6 weeks. (Fruits about 5 cm. in diameter)
Check.....	Twenty Ounce....	July 16, 1913.....	Wound, moisture	1	No infection
82-Apple bark.....	Twenty Ounce....	July 16, 1913.....	Inoculation in wound made by codling moth	2	No decay. Wound dried out

Massachusetts. They write: "No organism was to be found as the cause of the injury, and from the sequence of events there could be no reasonable doubt that the frost was the destructive agency."

The fungus theory was probably first favored by Alwood (1892:59), who attributed brown spot to *Phyllosticta pirina*. This organism has been regarded as the causal agent by several other writers — Kinney (1895 b), Lamson (1899), and others. In 1895 Stewart (1896) found a new species of *Phyllosticta*, described as *Phyllosticta limitata*, responsible for an epiphytotic of leaf spot on Long Island. In 1907 the fungus *Phyllosticta pirina* Sacc. was transferred to the genus *Coniothyrium* by Sheldon (1907), and the organism is now designated as *Coniothyrium pirina* (Sacc.) Sheldon. Another species of *Phyllosticta*, *P. prunicola* Sacc., is listed by Tubeuf and Smith⁷ as the cause of spotting of leaves of apple, plum, cherry, and apricot.

Alwood (1898 a) records, in addition to *P. pirina*, other fungi associated with the leaf spot, including *Hendersonia Mali* and *Sphaeropsis Malorum*. This is the earliest record that the writer has seen of the occurrence of the last-named fungus on leaves of apple, although Clinton (1902, and 1904:298) reports it as the common cause of leaf spot in Illinois and Connecticut in later years. The question of its relationship to the leaf spot disease, as well as that of other fungi, was subsequently studied by various pathologists.

Scott and Quaintance (1907) state that several different fungi, most prominent among which are *Phyllosticta* sp., *Hendersonia* sp., and *Sphaeropsis Malorum*, are connected with spots and may be responsible for the injury in some cases, yet they are not clear as to which are the real parasites. The following year the subject was investigated by Hartley, I. M. Lewis, and Scott and Rorer. Hartley (1908 b), in examining leaf spots of apple from the West Virginia Agricultural Experiment Station, found the following fungi: *Coryneum foliicolum*, *Coniothyrium pirina*, an undetermined species of the Tuberculariae, *Sphaeropsis Malorum*, *Monochaetia Mali*, *Pestalozzia breviseta*, *Phyllosticta limitata*, *Torula* (?) sp., *Macrosporium* sp., *Ascochyta* sp., *Phyllosticta* (?) *piriseda* (?), *Phoma Mali*, *Septoria piricola* (?), *Metasphaeria* sp., and an undetermined species of Leptostromaceae. He expresses the opinion that probably *Coryneum foliicolum* was formerly reported as a *Hendersonia*. The fact that the parasitism of *Coniothyrium pirina* was questioned by Stewart and Eustace (1902:228) led Hartley to investigate the pathogenicity of this species. He found that it would not affect healthy tissue, but that on the other hand, when wounds such as scalding, abrasion of epidermis, or punctures

⁷ Tubeuf, K. F. von, and Smith, W. G. Diseases of plants induced by cryptogamic parasites, page 463. 1897.

with hot and cold needles, were made in the tissue, the fungus in most cases grew and fruited. He concludes that *C. pirina* is a facultative, or wound, parasite only, and further that its ability to cause leaf spot in orchard trees to any extent remains to be demonstrated. In his opinion *Coryneum foliicolum* is less parasitic in the field than *Coniothyrium pirina*.

I. M. Lewis (1908:367) writes as follows regarding the leaf spot situation in New Hampshire: "Believing that the exact relation of all the fungi associated with the spots had not been thoroughly tested, an investigation was begun during the past summer to determine, if possible, the cause of the disease as it occurs in this State, and means of control by various spray mixtures." He states further (page 368 of same reference) that on isolation it was found that the fungi predominating were *Coniothyrium pirina*, *Coryneum foliicolum*, *Sphaeropsis Malorum*, *Alternaria* sp., and one of the Tuberculariae. To Hartley's total list of fungi associated with apple leaf spots, C. E. Lewis (1912:51) adds *Cladosporium herbarum* (Pers.) Link and *Dematium pullulans* De Bary, while Brooks and DeMeritt (1912:182) report the isolation of a *Fusarium*. The first series of experiments made by I. M. Lewis (1908), on August 1 showed that many inoculations did not result in infections; from this Lewis reasons that "the period at which the leaf is naturally infected is earlier in the spring and summer." This view is upheld by C. E. Lewis (1912:55), who concludes that the older leaves are not so susceptible to infection as are young leaves; the work of Brooks and DeMeritt (1912:190), however, in which they conclude that infection may occur until the last of August, indicates that the question of biologic races was a factor overlooked by both I. M. Lewis and C. E. Lewis. As regards the general conclusions of I. M. Lewis's work it may be further quoted (1908):

As a result of this season's inoculation experiments it is impossible to offer more than negative results as to the cause of the spots. I am of the opinion, however, that the fungus *Sphaeropsis malorum* which is known to cause canker of apple limbs and is an active parasite, will be found to be the primary cause of apple leaf spot. This supposition must, however, be supported by direct experiment before it can be definitely affirmed for the spots considered in this investigation.

The same year the results of further investigations by Scott and Rorer (1908) were published, in which a definite conclusion was reached. They state (page 49 of reference cited): "It was found that *Sphaeropsis malorum*, contrary to the general belief, is the cause of the disease." Regarding the associated species they conclude (page 52 of same reference):

Coniothyrium pirina (Sacc.) Sheldon, although it occurs abundantly on apple leaf spots, appears to have nothing to do with their formation.

The several other fungi that were tested, such as *Hendersonia* sp., *Coryneum* sp., *Pestalozzia* sp., and *Alternaria* sp., proved to be non-parasitic in these experiments and probably occur on leaf spots only as saprophytes.

The work of Scott and Rorer is practically confirmed by C. E. Lewis (1909). After making several inoculation experiments the latter writes (1912:55), in agreement with Hartley (1908 b), as follows:

The results of these inoculation experiments seem to indicate that *Sphaeropsis* is able to attack the leaves of orchard trees when they are inoculated early in the season under favorable conditions for growth. No spotting has been produced by any of the other fungi which have been tested although it has been found that they grow readily on dead spots which have been killed by other causes.

The investigations of I. M. Lewis began in 1908 and were continued by Brooks and DeMeritt in 1909. As Brooks and DeMeritt state (1912:183), the summer's work was not conclusive. Later cultural work revealed to them great variation in the nature of growth of different strains of the fungus, and also in the time required for spore production. It has been mentioned elsewhere (page 68) that these authors found morphological strains. This discovery led them to investigate the correlation between the morphological and biological variations of these forms. Their final conclusion (page 190 of reference cited) is: "Several strains of *Sphaeropsis Malorum* may be obtained, varying in general vigor and in power to produce diseased conditions. The large-spored form, with single-loculed, ostiolate pycnidia is largely responsible for the production of leaf spot."

The writer performed inoculation experiments in an attempt to produce apple leaf spot during the summers of 1910 to 1913 inclusive. In the experiments of 1910 the leaves of mature trees were inoculated in the following manner: Pycnidia were removed from pure culture and the spores liberated by crushing the fruiting bodies in a watch glass containing water. The contents of the watch glass were removed to an atomizer and the spores were sprayed on both surfaces of the leaves. In some cases the leaves were previously wounded with a needle, in others they were left uninjured. Data regarding the source of the fungus, the variety and age of the tree whose leaves were inoculated, the date of inoculation, the number of leaves inoculated, and the results, for 1910 to 1913, are given in table 3. It is to be noted that no moist chamber was provided in any of the experiments of 1910. In 1911 a series of inoculations made on May 27 resulted in infection where wounds and moisture were provided. The method of work here was the same as in 1910, except for the provision of a moist chamber. This consisted of a lamp chimney, into which the inoculated leaves were inserted and the ends of which were closed with damp cotton. The series of inoculations performed in July, 1910, and in August, 1911, should be compared. In neither case was a moist chamber used and the results were negative. In the experiments of 1912 and 1913 no spotting of the foliage was obtained by artificial inoculations. The writer has no explanation to offer. The explanation offered by Brooks

TABLE 3. RESULTS OF INOCULATIONS OF APPLE FOLIAGE, USING APPLE STRAINS OF *PHYSALOSPORA CYDONIAE*

Source and number of strain	Variety inoculated	Age of tree	Date of inoculation	Conditions provided	Number of leaves inoculated	Results
A-Twenty Ounce bark	Tompkins King, Rhode Island, Baldwin, Tolman, Swaar, Esopus, Yellow Transparent, Holland Pippin, Red Astrachan, Roxbury, Hubbardston	Mature, 1½/2 trees	July 18, 1910	Various as regards wounds. Both surfaces inoculated. No moisture provided	130	Failed
A-Twenty Ounce bark	Banana	3 years	May 27, 1911	Both surfaces inoculated. Some wounded, others not. Moisture provided for several hours in some cases	50	Where wound and moisture were provided, 100 per cent infection, with abundant pyrenidia after 2 weeks. Other leaves, including checks, showed no signs of disease
A-Twenty Ounce bark	Oliver	3 years	August 2, 1911	Both surfaces inoculated. Same wounded by needle pricks, others not. No moisture	24	Failed
57-Apple bark	Oliver	3 years	May 17, 1912	Both surfaces inoculated. Some wounded, others not. Moisture provided for several hours in some cases. Followed by drizzling rain	50	All failed
60-Apple bark	Oliver	3 years	May 20, 1912	Same as preceding	110	All failed
69-Apple bark	Oliver	3 years	May 29, 1912	Same as preceding	50	All failed
83-Esopus bark	Oliver	3 years	May 28, 1913	Same as preceding	50	All failed
90-Twenty Ounce bark	Oliver	3 years	May 28, 1913	Same as preceding	50	All failed

and DeMeritt (1912) for the leaf spot problem in New Hampshire is apparently not applicable under western New York conditions, since a variety of morphological forms was used in the inoculation work. The results obtained indicate that there is no correlation between morphological and biological characters with respect to pathogenicity.

CANKER OF APPLE. Waite (1898 a) was the first to attribute the canker to a fungous parasite; he suggested that *Schizophyllum commune* Fr. was the causal organism. Paddock (1899 b:183) found dark spores on the cankers, but supposed they belonged to some saprophytic form. However, he grew this organism, as well as *Schizophyllum commune*, on artificial media, and made pure culture inoculations in the following manner: A small opening was made in the bark by means of a sterilized knife, and a small quantity of material from bean stem cultures was inserted between the wood and the bark. The incision was covered with moist filter paper and kept moist for thirty-six hours. All the inoculations made in 1898 with the dark-spored fungus on apple trees were successful; other fungi failed and the wounds soon healed. Paddock's conclusions are summarized in the following words (page 184 of same reference): "These experiments showed conclusively that the dark-spored fungus can penetrate living apple-tree bark under certain conditions and produce a cankered condition of apple-tree limbs and also indicated that it may produce a diseased condition of pear-tree bark." Again he says (page 185 of same reference): "The result of over fifty inoculations made from cultures that were obtained from cankered apple tree limbs prove that the apple-tree canker of New York apple orchards is caused by a fungus of the genus *Sphaeropsis*." Over one thousand inoculations were made by him in 1899 (pages 200-201 of same reference) and only a very few gave negative results. He further asserts that the fungus causes canker of the quince if the material from pure culture is inserted under the bark, whereas under other conditions the experiments were not conclusive.

Paddock's work was continued (1900) for the purpose of confirming former results and to determine if possible the relationship between the species of *Sphaeropsis* that occur on various plants. He obtained cultures from apple fruit and apple bark, and inoculated the apple tree and other plants. The results were positive, thus further proving the pathogenicity of the organism, as well as establishing the identity of the fungus on fruit and bark. The conclusions reached by Paddock are essentially confirmed by C. E. Lewis (1909:188-189) and by McCready (1910).

The writer (1913:293) has summarized the results of earlier inoculation work as follows:

During the past summer [1913] several inoculations have been made with cultures from the ascospores of the ascomycetous fungus. The apple, pear, quince, crab apple, and other plants were inoculated, in each case wounds being made to serve as infection

courts. Three varieties of apples, namely Twenty Ounce, Baldwin, and Chenango Strawberry, were inoculated between May 20 and July 16, 1913. Eleven sets of experiments involving about seventy incisions were made, all of which gave positive infections, the checks remaining healthy.

The above quotation concerns the ascomycetous fungus from apple. A morphologically similar organism on *Hamamelis virginiana* did not produce infection, as is seen from the following statement (Hesler, 1913:293): "About twenty-five different inoculations were made [with the ascomycete from *H. virginiana*] on all the plants mentioned above but no infections occurred."

The writer has carried on inoculation experiments during the past four years, both in the greenhouse and in the field, the most of the work being directed toward the infection of bark tissues. The methods employed have already been described (page 79). The results discussed at this point concern only experiments in which apple strains of the fungus (*Phyalospora Cydoniae* Arnaud [= *Sphaeropsis Malorum* Berk.]) were used on apple itself. The more important points in this regard are shown in table 4, indicating the source of the strain, the variety and age of the tree inoculated, the conditions under which inoculations were made, the number of inoculations, and the general results. The infection work done in the summers of 1910, 1911, and 1912 was not conclusive, but with the use of various strains more satisfactory results were obtained in the season of 1913.

It may be noted in table 4 that races of the fungus came from different varieties of apple, isolations being made from fruit, leaf, and bark. It was desired to determine if possible whether strains obviously living under saprophytic conditions, as those following winter injury and fire blight, were capable of inducing bark injury, and to determine the nature of the parasitism of certain other strains that appeared to be parasitic. The results on these points are conflicting and it seems that the strains are as variable in their biological relationships as in their morphological characters. A race may produce infection on slightly wounded bark after it has been living under saprophytic conditions, for example, following fire blight. Again, those strains which in nature appear to be acting parasitically may prove to be weak parasites, producing infection only under certain conditions.

Conflicting results along this line have raised the question of individual variation among varieties of the host plant as regards susceptibility or immunity. It is possible that individual hosts in the same or in different orchards may differ in this respect, but conclusive data are not at hand with which to answer the question.

The variable results of inoculations of the apple with the apple fungus indicate that the production of infection requires the proper strain, a

TABLE 4. RESULTS OF INOCULATIONS OF PHYSALOSPORA CYDONIAE ON APPLE BARK. ONLY APPLE STRAINS INVOLVED

Source and number of strain	Variety inoculated	Age of tree	Date of inoculation	Conditions provided	Number of incisions	Results
A-Twenty Ounce bark.....	Twenty Ounce	40 years.....	July 20, 1910.....	Various conditions as regards wounds and moisture	17	100 per cent infection where wounds and moisture were provided. Other inoculations failed
A-Twenty Ounce bark.....	?	Mature.....	June 22, 1911.....	Wound by barely breaking bark	2	Very slight infection
Check.....	?	Mature.....	June 22, 1911.....	Wound by barely breaking bark	2	No infection
A-Twenty Ounce bark.....	?	Mature.....	June 22, 1911.....	Deep wound to wood.....	4	Rapid spread
Check.....	?	Mature.....	June 22, 1911.....	Deep wound to wood.....	4	No infection
A-Twenty Ounce bark.....	?	Young shoot.....	June 22, 1911.....	Deep wound to wood.....	3	Infection good
Check.....	?	Young shoot.....	June 22, 1911.....	Deep wound to wood.....	3	No infection
A-Twenty Ounce bark.....	Baldwin.....	2 years.....	February 15, 1912	Wound.....	4	Failed (in greenhouse)
A-Twenty Ounce bark.....	Twenty Ounce..	? (large).....	May 17, 1912.....	Slit in bark to wood.....	2	Canker formed within 6 weeks
22-Decorticated apple wood.....	Twenty Ounce..	? (large).....	May 17, 1912.....	Slit in bark to wood.....	2	Slight discoloration after 6 weeks
38-Rhode Island twig following fire blight	Twenty Ounce..	? (large).....	May 17, 1912.....	Slit in bark to wood.....	2	Fair growth after 6 weeks
25-Chenango apple leaf.....	Twenty Ounce..	? (large).....	May 17, 1912.....	Slit in bark to wood.....	2	Slight growth, limited by a marginal crack after 6 weeks
57-Sutton apple following winter injury	Twenty Ounce..	? (large).....	May 17, 1912.....	Slit in bark to wood.....	2	Very slight growth after 6 weeks
59-Apple fruit.....	Twenty Ounce..	? (large).....	May 17, 1912.....	Slit in bark to wood.....	2	Failed
60-Twenty Ounce bark.....	Oliver.....	3 years.....	May 20, 1912.....	No wound.....	2	Failed. Weather cloudy and rainy
Check.....	Oliver.....	3 years.....	May 20, 1912.....		2	No infection
60-Twenty Ounce bark.....	Oliver.....	3 years.....	May 20, 1912.....	Wound; slit to wood by scalpel	2	Failed

TABLE 4 (continued)

Source and number of strain	Variety inoculated	Age of tree	Date of inoculation	Conditions provided	Number of incisions	Results
Check.....	Oliver.....	3 years.....	May 20, 1912.....	Wound; slit to wood by scalpel	2	No infection
60-Twenty Ounce bark.....	Oliver.....	3 years.....	May 20, 1912.....	Bruise, breaking bark.....	2	Failed
Check.....	Oliver.....	3 years.....	May 20, 1912.....	Bruise, breaking bark.....	2	No infection
60-Twenty Ounce bark.....	Oliver.....	3 years.....	May 20, 1912.....	Winterkilled, wound by scalpel	2	Failed
Check.....	Oliver.....	3 years.....	May 20, 1912.....	Winterkilled, wound by scalpel	2	No infection
60-Twenty Ounce bark.....	Oliver.....	3 years.....	May 20, 1912.....	Winterkilled, no wound.....	2	Failed
Check.....	Oliver.....	3 years.....	May 20, 1912.....	Winterkilled, no wound.....	2	No infection
38-Rhode Island twig following fire blight	Twenty Ounce.....	Mature.....	June 27, 1912.....	Wound to wood; moist cotton for several hours	2	Canker 1.5 cm. in diameter
60-Twenty Ounce bark.....	Twenty Ounce.....	Mature.....	June 27, 1912.....	Wound to wood; moist cotton for several hours	2	Failed
70 Walbridge apple tree.....	Twenty Ounce.....	Mature.....	June 27, 1912.....	Wound to wood; moist cotton for several hours	2	Very slight discoloration
A-Twenty Ounce bark.....	Twenty Ounce.....	Mature.....	July 1, 1912.....	Wound to wood; moist chamber for several days	2	Canker 3 cm. in diameter after 18 days. Secondary spreading in 1913
22-Decorticated apple wood.....	Twenty Ounce.....	Mature.....	July 1, 1912.....	Wound to wood; moist chamber for several days	2	Not very satisfactory in 1912. Spreading in May, 1913; pycnidia
25-Chenango apple leaf.....	Twenty Ounce.....	Mature.....	July 1, 1912.....	Wound to wood; moist chamber for several days	2	2 cm. in diameter. Slight spread in 1913
52-Apple leaf.....	Twenty Ounce.....	Mature.....	July 1, 1912.....	Wound to wood; moist chamber for several days	2	Slight discoloration. No spread in 1913
60-Twenty Ounce bark.....	Twenty Ounce.....	Mature.....	July 1, 1912.....	Wound to wood; moist chamber for several days	2	3.5 cm. in diameter 1912. No advance in 1913

61-Baldwin bark.	Twenty Ounce..	Mature.....	July 1, 1912.....	Wound to wood; moist chamber for several days	5	2.5 x 6.5 cm. each. A marginal crevice August 24, 1912. Spread in 1913: 1. No increase 2. No increase 3. Limb 5 cm. in diameter, half girdled in May and finally girdled in September. Pycnidia 4. No increase 5. 7 x 12.5 cm. Pycnidia
71-Culture from Chas. E. Brooks	Twenty Ounce..	Mature.....	July 1, 1912.....	Wound to wood; moist chamber for several days	2	2.5 x 4 cm. by July 12. No advance in 1913
A-Twenty Ounce bark.	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber for several days	2	Failed
22-Decorticated apple wood....	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber for several days	2	1 cm. in diameter
25-Chenango apple leaf.....	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber for several days	2	Failed
38-Rhode Island twig following fire blight	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber for several days	2	1 x 1.7 cm.
52-Apple leaf.....	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber for several days	2	Failed
60-Twenty Ounce bark.....	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber for several days	2	1 cm. in diameter
61-Baldwin bark.	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber for several days	2	Twig 1 cm. in diameter, almost girdled
71-Culture from Chas. E. Brooks	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber for several days	2	Slight infection
A-Twenty Ounce bark.	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber	2	Failed
71-Culture from Chas. E. Brooks	Twenty Ounce..	Mature.....	July 10, 1912.....	Wound to wood; moist chamber	2	Failed
22-Decorticated apple wood....	Twenty Ounce..	Mature.....	July 22, 1912.....	Wound to wood; moist chamber	2	Failed
38-Rhode Island twig following fire blight	Twenty Ounce..	Mature.....	July 22, 1912.....	Wound to wood; moist chamber	2	Very slight
52-Apple leaf.....	Twenty Ounce..	Mature.....	July 22, 1912.....	Wound to wood; moist chamber	2	Failed

TABLE 4 (continued)

Source and number of strain	Variety inoculated	Age of tree	Date of inoculation	Conditions provided	Number of incisions	Results
60-Twenty Ounce bark.....	Twenty Ounce..	Mature.....	July 22, 1912.....	Wound to wood; moist chamber	2	Slight
61-Baldwin bark.....	Twenty Ounce..	Mature.....	July 22, 1912.....	Wound to wood; moist chamber	2	Slight
70-Walbridge apple tree.....	Twenty Ounce..	Mature.....	July 22, 1912.....	Wound to wood; moist chamber	2	Slight
71-Culture from Chas. E. Brooks	Twenty Ounce..	Mature.....	July 22, 1912.....	Wound to wood; moist chamber	2	2.5 cm. in diameter. Marginal crack after 30 days
25-Chenango apple leaf.....	Twenty Ounce..	Mature.....	August 17, 1912...	Wound to wood; moist chamber	2	Slight discoloration
68-Apple bark.....	Twenty Ounce..	Mature.....	August 17, 1912...	Wound to wood; moist chamber	2	Doubtful
25-Chenango apple leaf.....	Twenty Ounce..	Mature.....	August 17, 1912...	Wound to wood; moist chamber	2	Doubtful
68-Apple bark.....	Twenty Ounce..	Mature.....	August 17, 1912...	Wound to wood; moist chamber	2	Failed
82-Apple bark.....	Lady Blush.....	Mature.....	May 9, 1913.....	Wound by cut; no moisture	2	Failed
82-Apple bark.....	Lady Blush.....	Mature.....	May 9, 1913.....	Bark broken by bruise of shoe; no moisture	2	Failed
82-Apple bark.....	Lady Blush.....	Mature.....	May 9, 1913.....	Natural wound left by sucker	2	Failed
82-Apple bark.....	Lady Blush.....	Mature.....	May 9, 1913.....	Wound by cut; no moisture	2	Failed
82-Apple bark.....	Twenty Ounce..	Mature.....	May 12, 1913.....	Wound to wood by cut.....	4	Failed
82-Apple bark.....	Twenty Ounce..	Mature.....	May 12, 1913.....	Bruise by shoe.....	3	Failed
82-Apple bark.....	Twenty Ounce..	Mature.....	May 20, 1913.....	Bruise by shoe on 8th day previous	5	100 per cent infection. Slowly spreading. Growth stopped by June 15
Check.....	Twenty Ounce..	Mature.....	May 20, 1913.....	Bruise by shoe on 8th day previous	5	No infection

82-Apple bark.....	Twenty Ounce..	Mature.....	May 20, 1913.....	Freshly bruised by shoe....	2	Failed
82-Apple bark.....	Twenty Ounce..	Mature.....	May 20, 1913.....	Bruise made 8 days previous	2	100 per cent infection. Slowly spreading. Growth ceased by June 15
82-Apple bark.....	Twenty Ounce..	Mature.....	May 22, 1913.....	Wound by cut.....	6	50 per cent infection (mycelium used). Cankers 2 cm. in diameter after 2 months
82-Apple bark.....	Twenty Ounce..	Mature.....	May 22, 1913.....	Wound by cut.....	1	Failed (spores used)
Check.....	Twenty Ounce..	Mature.....	May 22, 1913.....	Wound by cut.....	1	No infection
82-Apple bark.....	Twenty Ounce..	Mature.....	June 6, 1913.....	Wound by cut.....	5	100 per cent infection. Cankers about 2 x 3 cm. after 7 weeks
82-Apple bark.....	Twenty Ounce..	Mature.....	June 18, 1913.....	Wound barely through epidermis	3	Cankers 1.5 cm. in diameter after 5 weeks
82-Apple bark.....	Twenty Ounce..	Mature.....	June 18, 1913.....	Wound to wood.....	3	Cankers 2 cm. in diameter after 5 weeks
82-Apple bark.....	Twenty Ounce..	Mature.....	July 16, 1913.....	Wound to wood.....	4	3 slight infections; 1 canker 1 cm. in diameter
Check.....	Baldwin twigs..	Mature.....	July 16, 1913.....	Wound to wood.....	1	No infection
82-Apple bark.....	Chenango.....	Mature.....	July 16, 1913.....	Wound to wood.....	4	2 slight infections; 2 cankers 1 x 1.3 cm. after 1 week
82-Apple bark.....	Twenty Ounce..	Mature.....	July 16, 1913.....	Wound to wood.....	9	7 cankers developed, averaging 1 cm. after 2 weeks
Check.....	Twenty Ounce..	Mature.....	July 16, 1913.....	Wound to wood.....	3	No infection
82-Apple bark.....	Twenty Ounce..	Mature.....	July 17, 1913.....	Wound to wood.....	5	5 cankers, averaging 1 cm. after 1 week
Check.....	Twenty Ounce..	Mature.....	July 17, 1913.....	Wound to wood.....	1	No infection
82-Apple bark.....	Twenty Ounce..	Mature.....	July 16, 1913.....	Wound by inserting red-hot scalpel	4	4 cankers, averaging 1.5 cm. after 1 week
Check.....	Twenty Ounce..	Mature.....	July 16, 1913.....	Wound by inserting red-hot scalpel	1	No infection
82-Apple bark.....	Twenty Ounce..	Mature.....	July 16, 1913.....	Wound by bruise.....	4	4 cankers averaging 1 x 1.5 cm. after 1 week
82-Apple bark.....	Baldwin.....	2 years.....	December 9, 1913.	Wound by slit with scalpel..	4	4 cankers after 1 week
Check.....	Baldwin.....	2 years.....	December 9, 1913.	Wound by slit with scalpel..	2	No infections

TABLE 4 (concluded)

Source and number of strain	Variety inoculated	Age of tree	Date of inoculation	Conditions provided	Number of incisions	Results
82-Apple bark.....	Baldwin.....	3 years.....	July 25, 1914.....	Wound by slit with scalpel..	9	9 cankers, averaging about 1 x 3 cm. after 1 month
82-Apple bark.....	Northern Spy.....	3 years.....	July 30, 1914.....	Wound by slit with scalpel..	9	All developed cankers, averaging 1 x 3 to 4 cm. after a month
82-Apple bark.....	Baldwin.....	3 years.....	July 30, 1914.....	Wound by slit with scalpel..	1	Canker 1.4 x 4.8 cm. after 1 month
82-Apple bark.....	Baldwin.....	3 years.....	July 30, 1914.....	Wound by slit with scalpel..	6	Cankers in each case, averaging 1 x 7 cm. after 1 month
82-Apple bark.....	Gilliflower.....	Mature.....	October 5, 1914...	Wound by slit with scalpel..	4	Failed

wound in which to initiate the relationship, and moisture until infection has occurred.

Associated species.—It has been noted' elsewhere that the fungus *Schizophyllum commune* Fr. was suspected as being the cause of canker (Waite, 1898 a). This apprehension was undoubtedly based on association of the fruiting body of the organism with the lesions, as it is common to find this fungus fruiting on old cankered limbs. Paddock (1898 a) cultured this species and after inoculating apple limbs concluded that it was not the cause of the disease.

The rôle of associated species in the production of canker on apple is taken up somewhat at length by C. E. Lewis (1912). In Maine the fungi most frequently found on dying twigs and branches of apple are *Sphaeropsis Malorum*, *Myxosporium corticolum* Edgerton, *Coryneum foliicolum* Fckl., *Cytospora* sp., *Phoma Mali* Schulz & Sacc., and *Coniothyrium pirina* (Sacc.) Sheldon. Those often developing in plate cultures were: *Phyllosticta limitata* Peck, *Dematium pullulans* De Bary, *Cladosporium herbarum* (Pers.) Link, *Alternaria* sp., *Macrosporium* sp., *Fusarium* sp., *Epicoccum* sp., and *Glomerella cingulata* (Stonem.) Sp. & von Sch. To this list the writer adds *Septoria* sp., *Cephalothecium roseum* Cda., and *Aspergillus* sp. C. E. Lewis (1912:62) concludes "that *Coryneum* and *Phoma* can cause considerable injury to young trees and branches of orchard trees. *Myxosporium* and *Cytospora* do not attack healthy branches but it seems probable that they attack weakened branches." The writer's results with the various associated fungi may be summarized by the statement that none of the species enumerated above made growth on apple bark.

CROSS-INOCULATIONS AND HOST RELATIONSHIPS (Plates VIII, IX, XI, XIV). The identity of the various species of *Sphaeropsis* on the same and on different plants has been established in certain cases. That the species on the fruit of apple is the same as that on the bark was proved by Paddock (1899 b, 1900) several years ago, and confirmed by Potebnia (1907) more recently. A similar relationship for the fruit and foliage forms of the fungus has been proved by Morse (1909), while Scott and Rorer (1908) have demonstrated the identity of the organism on leaves and bark. The ability of these three forms to grow interchangeably on the several organs of the apple is no longer questioned, and the results of previous investigations are essentially confirmed by the writer in tables 1, 2, 3, and 4.

The pycnidial stage of *Physalospora Cydoniae* Arnaud (*Sphaeropsis Malorum* Berk.) has been collected by various investigators (Paddock, Arnaud, the writer, and others) on the following plants: apple (*Pyrus malus* L.), apricot (*Prunus armeniaca* L.), alder (*Alnus glutinosa* Gaertn.),

TABLE 5. RESULTS OF CROSS-INOCULATIONS WITH PURE CULTURES OF PHYSALOSPORA CYDONIAE FROM VARIOUS HOSTS*

Host from which fungus was obtained	Host inoculated									
	Apple (<i>Pyrus malus</i>)		Quince (<i>Cydonia vulgaris</i>)		Pear (<i>Pyrus communis</i>)		Crab (<i>Pyrus cornuaria</i>)		Peach (<i>Pyrus persica</i>)	
Apple (<i>Pyrus malus</i>)	Bark	259 +210 -49	Fruit	48 +45 -3	Foliage	334 +30 -104	Bark	9 +7 -2	Bark	5 +2 -5
	Fruit	1 +1 +10	Fruit	1 +1 +10	Foliage	10 +10 -454	Bark	14 +2 -13	Bark	2 +1 -1
	Foliage	10 +4 -9	Foliage	512 +58 -454	Foliage	27 +10 -17	Bark	2 +2 -3	Bark	9 -9 -1
	Wood	4 +3 -1	Wood		Wood		Bark	2 +2	Bark	5 +2 -5
Quince (<i>Cydonia vulgaris</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2
Pear (<i>Pyrus communis</i>)	Fruit	3 +3 -1	Fruit		Fruit		Bark	2 +2 -2	Bark	2 +2 -2
							Bark	2 +2 -2	Bark	2 +2 -2
							Bark	2 +2 -2	Bark	2 +2 -2
							Bark	2 +2 -2	Bark	2 +2 -2
Maple (<i>Acer pensylvanicum</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2
Mulberry (<i>Morus alba</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2
Sumac (<i>Rhus typhina</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2
Sweet cherry (<i>Prunus avium</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2
Witch-hazel (<i>Hamamelis virginiana</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2
Blm (<i>Ulmus americana</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2
Ash (<i>Fraxinus americana</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2
Chestnut (<i>Castanea dentata</i>)	Bark	10 +5 -5	Fruit	4 +4 -2	Foliage	10 -10 -10	Bark	2 +2 -2	Bark	2 +2 -2
	Fruit	6 +4 -2	Fruit	4 +4 -2	Foliage	4 -4 -4	Bark	2 +2 -2	Bark	2 +2 -2
	Foliage	6 +1 -2	Foliage		Foliage		Bark	2 +2 -2	Bark	2 +2 -2
	Bark	10 +6 -4	Bark	3 +3 -1	Bark	11 -11 -11	Bark	4 +4 -2	Bark	4 +4 -2

Crab (<i>Pyrus coronaria</i>)	Bark	12 +10 -2	1 -1	50 -50	5 -5	4 +4	4 +2 -2	4 +2	2 -2	2 -2	2 -2	4 -4	...
Peach (<i>Prunus persica</i>)	Bark	6 +1 -5	8 +6 -2	30 -30	4 -4	...	12 +10 -2	...	...	...	...	2 -2	...
Sweet cherry (<i>Prunus avium</i>)	Bark	4 +4	...	...	4 -4	...	2 +2	2 +2	5 -5	2 -2	2 -2	2 -2	...
Sumac (<i>Rhus typhina</i>)	Bark	11 +3 -8	8 +7 -1	...	5 -5	2 +2	4 +4 -2	4 +2	2 -2	2 -2	2 -2	4 -4	...
Mulberry (<i>Morus alba</i>)	Bark	12 +6 -6	1 +1	...	5 -5	6 +3 -3	7 +2 -5	10 +4 -6	...	7 -7	4 +2 -2	8 -8	...
Maple (<i>Acer spicatum</i>)	Bark	6 +4 -2	...	...	6 +1 -5	5 +4 -1	4 +2 -2	4 -4	3 +1 -2	2 -2	2 -2	2 -2	...
Ash (<i>Fraxinus americana</i>)	Bark	...	...	...	2 -2	3 +1 -2	2 -2	2 +2	...	2 -2	2 -2	2 -2	...
Witch-hazel (<i>Hamamelis virginiana</i>)	Bark	7 +2 -5	...	...	2 -2	4 +2 -2	4 -4	2 -2	2 -2	2 -2	2 -2	2 -2	...
Elm (<i>Ulmus americana</i>)	Bark	3 +3	...	...	2 -2	2 +2	2 -2	2 -2	...	...	...	2 -2	...
Basswood (<i>Tilia americana</i>)	Bark	3 +2	...	...	2 -2	2 +2 -1	2 -2	2 -2	...	...	...	...	...
Chestnut oak (<i>Quercus prinus</i>)	Bark	21 +21	...	...	...	...	...	...	...	3 -3	6 -6	10 +10	...

*The first number indicates the number of inoculations made. The numbers with a plus sign represent the number of infections; the minus sign indicates failure to infect.

ash (*Fraxinus americana* L.), basswood (*Tilia americana* L.), bittersweet (*Celastrus scandens* L.), box elder (*Acer negundo* L.), cherry (*Prunus avium* L., *P. pennsylvanica* L., *P. virginiana* L.), cherry laurel (*Prunus lauro-cerasus* L.), crab (*Pyrus coronaria* L.), currant (*Ribes* sp.), dogwood (*Cornus stolonifera* Michx., *C. sanguinea* L.), elder (*Sambucus canadensis* L.), elm (*Ulmus americana* L.), fig (*Ficus carica* L.), grape (*Vitis* sp.), hawthorn (*Crataegus oxyacantha* L.), hop hornbeam (*Ostrya virginica* [Mill.] K. Koch), lilac (*Syringa vulgaris* L.), maple (*Acer saccharinum* L.), mulberry (*Morus alba* L.), oak (*Quercus alba* L., *Q. prinus* L.), osage orange (*Maclura pomifera* [Raf.] Schneider), peach (*Prunus persica* [L.] Stokes), pear (*Pyrus communis* L.), persimmon (*Diospyros virginiana* L.), pine (*Pinus strobus* L.), plum (*Prunus domestica* L., *P. triflora* Roxbg.), quince (*Cydonia vulgaris* Pers.), rose (*Rosa canina* L., *Rosa* sp.), rose of sharon (*Hibiscus syriacus* L.), spicebush (*Benzoin aestivale* [L.] Nees), sumac (*Rhus typhina* L., *R. glabra* L.), sycamore (*Platanus orientalis* L.), witch-hazel (*Hamamelis virginiana* L.). Where fresh material was available the writer cultured the fungus from all these plants except three — dogwood, lilac, and rose of sharon, which have just been collected — and these cultures were used in all cross-inoculation experiments. The source of the cultures used, the plants inoculated, and the results, are shown in table 5. The methods used were similar to those described in connection with the inoculation experiments on apple fruit (page 79). In some of the earlier experiments a moist chamber was used consisting of a petri-dish lid, the inner margin of which was lined with damp cotton. Later the glass lid was eliminated and a cotton cap, made by rolling a strip of cotton about the finger, was employed. Moisture was provided at the time of inoculation and was added daily for several (usually from three to seven) days subsequently.

The results of cross-inoculations were not conclusive, particularly in cases in which the fungus failed to develop. Failure to produce infection may be accounted for in two ways: either the fungus was not parasitic on the plant inoculated, or conditions favorable for infection were lacking. In many cases further trials are desirable.

In nature the fungus rarely shows a parasitic tendency on wild plants — with the exception of *Quercus prinus* (see Rankin, 1914) — but it is generally found developing on dead and fallen twigs; cankers have not been observed which could with certainty be attributed to this organism. On cultivated plants it commonly shows the same habits as it does on wild plants, or it may develop in healthy tissues, resulting in the formation of a canker. Here, then, on the cultivated plants are found both saprophytic and parasitic tendencies. This phenomenon is in accordance with the commonly accepted theory that parasitism originated from sapro-

phytism. This is what is to be expected; and the theory is further supported by inoculation data which show that the strains from wild plants may be induced to infect cultivated plants. The reverse process — that is, the infection of wild plants with strains from either cultivated or wild forms — has been almost wholly unsuccessful in the writer's experience. This in the main confirms the work of Paddock (1899 b, 1900).

On certain wild plants there is found a saprophytic race which, when carried to cultivated forms such as the apple or the pear, acts as a wound parasite. On cultivated plants the fungus follows fire blight and winter injury, and hence is a saprophyte, but the latter strains are not necessarily obligate saprophytes since they have been induced to cause canker by artificial inoculation. This is shown by strains 22, 38, 57, and 70 in table 4. It does not appear, therefore, that the fungus can be segregated easily into physiological groups, since varying degrees of parasitism are exhibited by a given race.

From the experiments described and tabulated it is clear that there is considerable variation in the virulence of races, but just how long a given parasitic strain will retain this mode of life is a difficult question to answer. The ability of the organism to act as a wound parasite, and to adapt itself naturally to the saprophytic mode, makes it a serious pest from the standpoint of control. Its ability to remain saprophytic indefinitely until the host is injured in some way only increases the difficulty in alleviating the disease.

NAMES AND SYNONYMY

The work that has been done on cross-inoculations and on the morphology of *Sphaeropsis* from several different plants makes it apparent that there is one large polymorphic species. It is true that many inoculations failed, and that two given races may differ widely in their morphology; but there is considerable evidence that these characters are variable and are not important in taxonomic considerations.

The several forms as they have been described from time to time have been given a specific name, usually one for every host plant. This procedure has resulted in the accumulation of a large number of specific names which could now be disposed of only by the examination of type material of each so-called species. Several generic names have become involved in the synonymy of the fungus, due to the indefinite limitations and wide variations, and consequent overlapping, of certain form-genera. Saccardo (1884 a) believed *Sphaeropsis Malorum* Berk. to be a *Phoma*, since it was originally described by Berkeley (1836) as having yellowish green spores. It is now known that the young spores have this color characteristically, and furthermore Dr. C. L. Shear, who has seen Berkeley's

type, has stated (in conversation with Dr. Donald Reddick, of Cornell University) that the organism is unquestionably identical with *Sphaeropsis Malorum* as now recognized. Subsequent to Saccardo's use of the name *Phoma*, this genus was divided into *Phoma* and *Macrophoma* — the former genus containing species with spores less than 15μ long, the latter containing species with spores more than 15μ long. Thus *Phoma Malorum* (Berk.) Sacc. was renamed by Berlese and Voglino (1886) as *Macrophoma Malorum* (Berk.) Berl. & Vogl.

It appears that certain species of *Sphaeropsis* have been confused with those of *Diplodia*. The two genera are separated on the basis of one-celled spores in the former and two-celled spores in the latter. But both genera fail in their chief distinction, so that mycologists have been misled on this point. Fückel (1869:393) used the name *Diplodia pseudo-diplodia* Fckl. in describing the fungus on branches of apple; elsewhere (page 395 of same reference) he used *Diplodia Malorum* Fckl.

It has been noted previously that the pycnidium sometimes approaches and even reaches the condition characteristic of the form-genus *Botryodiplodia*. It becomes evident that the names of certain species of this genus may stand only as synonyms of *Physalospora Cydoniae* Arnaud.

The origin of several of these synonyms has been discussed in an earlier paper by the writer (1912), to which the reader is referred. At that time it seemed desirable to attempt the selection of the name that should, according to the rules of priority, be applied to the pycnidial stage. Recently, however, the perfect stage of the fungus has been found, and thus the selection of a specific name from the pycnidial forms is of minor importance. The generic name now becomes *Physalospora*, and the writer has chosen *Cydoniae* as the specific name. The following statements bearing on this question are quoted from another paper by the writer (1913:295):

The problem of selecting a specific name is somewhat perplexing. The organism with which the writer is dealing strongly resembles *P. Cydoniae* Arnaud but we have not seen his type material and there remains the question of whether his fungus has not been previously described. In this connection a few species which suggest this possibility may be noted: *P. entaxia* E. & E., *P. festucae* (Lib.) Sacc. and *P. nigropunctata* Romell, the last on limbs of *Pyrus malus* according to Saccardo. Until further data are at hand the writer is inclined to accept tentatively the name *Physalospora Cydoniae* Arnaud.

Soon after the above-mentioned paper appeared in print, the writer received from Arnaud a glycerin-jelly mount of his type material. It is clear that morphologically the organism is identical with the one described by the writer (1913) under the same name. But the question of the specific name is still unsettled, for it is not improbable, as stated above, that the organism has been previously described under some other specific name. This problem, as in the case of the several pycnidial

forms, would involve the study of type material, which as yet has not been available to the writer. Under the circumstances Arnaud's specific name will be retained tentatively by the writer. The following is a partial list of species which are concerned in the synonymy of the fungus; citations to literature are also given:

Physalospora Cydoniae Arnaud. École Nat. d'Agr. Montpellier. Ann. 12:7. 1912.

- Sphaeria sumachi* Schw. Amer. Phil. Soc. Trans. n. s. 4:205. 1834.
Sphaeria rhuina Schw. Amer. Phil. Soc. Trans. n. s. 4:218. 1834.
Sphaeria pomorum Schw. Amer. Phil. Soc. Trans. n. s. 4:219. 1834.
Sphaeria Malorum Berk. English Flora 5:257-258. 1836.
Diplodia pseudodiplodia Fckl. Symbolae Mycologicae, p. 393. 1869.
Diplodia Malorum Fckl. Symbolae Mycologicae, p. 395. 1869.
Sphaeropsis Cydoniae C. & E. Grevillea 6:84. 1878.
Sphaeropsis Malorum Peck. Sylloge Fungorum 3:294. 1884.

Several years ago Ellis (1880) studied the variability of *Botryosphaeria fuliginosa* (M. & N.) E. & E. [= *Sphaeria Quercuum* Schw.], and came to the conclusion that this species really included at least eighteen so-called species. Among these may be noted, using Ellis's nomenclature, *Sphaeria entaxia* C. & E. [= *Physalospora entaxia* Sacc.], *S. viscosa* C. & E. [= *P. viscosa* Sacc.], *S. erratica* C. & E. [= *P. erratica* Sacc.], *Botryosphaeria pustulata* Sacc., and others. Ellis found wide variation with respect to stromatic formation. Sometimes the perithecia were scattered and distinct, and again they were confluent and united in a stroma. Considerable range with respect to the ostiolum is also noted by Ellis (1880). But, as stated by Ellis and Everhart (1892:547), certain forms of *Botryosphaeria fuliginosa*—those lacking a stroma—are removed to the genus *Physalospora*. It may be that under certain conditions *P. Cydoniae* develops a stroma, but such a tendency has not been observed; for this reason the generic name *Physalospora* is selected.

LIFE HISTORY STUDIES

The mature morphological structures of the fungus have been described, so that the following paragraphs concern only the successive stages in its development: where and in what condition the organism hibernates, the manner in which it is disseminated, its entrance and effects on the plants attacked, and the development of certain of its fruiting bodies.

SOURCE OF THE INOCULUM. The fungus passes the winter as mycelium in the tissues of the host and as pycnospores in pycnidia. If a canker is examined in the spring when growth is resumed by the host plant, the margin of the old lesion may show discoloration. The writer has frequently planted bits of the bark from the edge of a canker in agar plates, pure cultures resulting. This is evidence of the resumption of growth of the mycelium in the old lesion. It is stated by Caesar (1909)

that as a rule the fungus does not die out but continues to extend in every direction year after year, finally girdling the limb. In this connection Paddock (1899 b:189) writes as follows: "In some instances the mycelium apparently lives over winter and continues its growth the following spring. The formation of the largest cankers can scarcely be explained in any other way." He adds, however, that "in all of the inoculations made in the spring of 1898, in only one instance did the resulting canker enlarge any during the present season."

The writer's experience in this regard is somewhat similar, although more cankers have enlarged the second year than is intimated by Paddock. On this point there appears to be a difference in orchards. In one orchard the author counted forty cankers on three trees on May 20, 1912. All were formed at least one year previously, but only one showed advancement at the margin on this date. In other orchards a majority of the cankers were enlarging. The vitality of the trees does not seem to explain the difference displayed, since this quality appeared similar in the two cases mentioned. The trees in the two orchards were of the same variety (Twenty Ounce); here the question of physiological races may throw light on the subject.

It has been suggested that the mycelium may winter over in mummified fruit, and that in cases in which the fruit hangs on the tree the hyphæ may pass into the branch supporting it (Anonymous reference, 1899 c, page 126). The latter condition has not been observed by the writer. In some cases the mycelium hibernates in the mummified fruit, but the passage of the hyphæ down into the branch and the resulting development of a canker is questionable.

The growth of the mycelium at the edge of a lesion, as described above, does not account for new and isolated cankers. The phenomenon results nevertheless, indirectly, in a source of inoculum, in that fruit bodies may develop on the newly infected margin and so furnish spores which may cause other infections directly. The young cankers originate by the agency of the spores of the fungus.

It is a common thing to find, in the winter and spring, pycnidia bearing mature spores on mummified fruits. These fruiting bodies may be observed also on cankers and on fallen twigs, bark, and leaves. In western New York cankers and dead twigs are the most important sources of the inoculum.

The hibernation of pycnosporos on the various organs of the tree is reported by a number of investigators: on the bark, fallen twigs, and cankers, by Paddock (1899 b:189), by Brooks and DeMeritt (1912:189), and by Scott and Rorer (1908:52); on fallen leaves by Reed and Cooley (1911); on the fruit, as mummies hanging on the tree or fallen, by Scott

and Rorer (1908:52) and by Brooks (1909). Other writers have confirmed all these observations. These spores in winter have been placed in room temperature, and were subsequently found to be capable of germination in tap water. There is evidence that pycnospores may also winter over scattered about on the bark; they have been found in early spring before the pycnidia have entered their period of spore discharge.

The rôle of the ascosporic stage in hibernation is not certain. As previously indicated, the perithecia are rare on *Pyrus malus* in New York, and it would seem, therefore, that the ascospores from this source are of relatively little importance in initiating infections. Whether this stage is common on other plants in this State, and important as a source of inoculum, are matters remaining to be investigated.

METHOD OF SPORE DISCHARGE. The manner in which the pycnospores escape from the pycnidium has not been fully described, so far as the writer knows. Berkeley (1836) makes mention of the process as follows: "When dry the ostiolum is frequently crowned with a short minute tendrill oozing out from the perithecium." Halsted (1892) writes: "The ripe spores . . . form long, slender coils as they are pushed out of the small hole in the skin." Similar descriptions of the process are given by Clinton (1902) and by Evans (1910).

If a bit of bark or of fruit bearing pycnidia is placed under moist conditions, in a few hours dark masses of spores in the form of a coil may be seen (Plate XIII, 4). In one experiment the following notes were taken: "Twigs of an apple strain (no. 82) bearing mature brown pycnospores were placed in a moist chamber on May 20, 1913, at 3 p. m. By noon on May 23 the dark masses could be seen with the naked eye. These masses measure about 200 to 250 μ by 400 to 450 μ ." At this time it was observed that the masses stood out from the surface of the bark nearly five millimeters. They were very easily removed by a needle and examined under the microscope. It was observed that on the side of the mass nearest the bark several spores had germinated, and the resulting hyphæ had raised the mass away from the surface of the bark. A drop of water was added to one mass, which behaved as follows: In a few seconds the mass began to segregate, and single spores or groups of a few moved very quickly, with a darting motion, from the mass. They were at first thrown through the drop of water as far as 85 μ and they then moved slowly away. After forty-five minutes the spores had scattered in all directions, from 1500 to 2800 μ from the original point of departure. The coil in some cases contained about 1500 mature spores and in some experiments proved to be at least one millimeter in length. It has been estimated by the writer that there may be as many as 150 pycnidia on a square centimeter of the surface of an apple fruit; this would furnish

approximately 225,000 spores for the given unit area, or 1,406,250 spores per square inch of apple surface.

As stated in the notes quoted above, the spore coils were found on the bark three days after moisture was supplied. But this does not mean that all this time was involved in the process of escape. The pycnidia were found to be closed at first and considerable time must have been consumed in their opening. In other experiments as long a period as five days was necessary to effect the opening in some cases. The time that actually intervenes between admission of moisture to the spore mass within the pycnidium and the coiling of the spores is negligible. Pycnidia have been removed from dry bark in the summer, placed on dry slides, and observed with the microscope. If a drop of water is then applied, the spores will ooze out immediately provided the ostiole is open. Their fate after coiling seems to depend on the amount of moisture present. If a beating rain is falling, undoubtedly the spores are carried by the spattering drops toward the ground and perchance lodge on the foliage or on the branches. In case of a dew, unquestionably the coil behaves as described above; that is, some of the spores on the lower side of the mass germinate, the resulting web of germ tubes raising the spores from the bark, when they may be lifted by the wind. Again, if the mass encounters a drop of water the gelatinous material quickly expands and the spores are scattered throughout the drop. It is conceivable that the drop may be carried by the wind for a short distance at least.

TIME OF SPORE DISCHARGE. The time of the year when spores are disseminated may be approximated by noting the date of the first appearance of the diseased spots, and by keeping careful watch of the behavior of the pycnidia in the field. It is believed by I. M. Lewis (1908) that the period when foliage is naturally infected is early in the spring and summer. The same opinion is expressed by Brooks (1909), who states that the indications are that leaf infection ceases in June. Later, however, Brooks and DeMeritt (1912:189) attach little value to this statement, expressing the opinion that the nature of the fungus was a factor overlooked by previous investigators and that weather conditions may play a part in determination of the time of infection.

Paddock (1899 b:189) states that many spores remain in pycnidia until the following spring, when they are disseminated. Wolf (1910) has made a study of the prevalence of fungus spores in orchards by exposing agar plates, and his conclusions are expressed as follows (page 202 of reference cited): "At no time during the period in which exposures were made (September to May, inclusive) were viable spores of *Sphaeropsis malorum* present in the atmosphere of the orchard." McCready (1910) reports mature spores as being disseminated from cankers as early as the first

week in April, and states that at the same time a large number of spores were found in the orchard on rotten apples. In Virginia, at Blacksburg, Reed and Cooley (1911) found spores being discharged from pycnidia on leaves on June 25, 1910. Whether spores are liberated at an earlier date these authors do not state, but it is probable that such is the case.

From observations made by the writer it seems that the date of first discharge in the spring varies with the season. Apparently the ostiole does not open at a temperature below 60° F. (15.5° C.) or in the absence of moisture, and a period of humidity of several hours duration is necessary. The dates for spore discharge observed at Byron, New York, are May 16, 1912, and May 12 and 23, 1913. In 1911 spores were found coiling on July 17, but the process must have occurred earlier. That they continue to be liberated throughout the summer is shown by the appearance of new infections on foliage from May until September 20, 1913. In 1911 several young spots were found on bark in the middle of August. Ripe and green fruit infections also show that spores are disseminated in August and September.

AGENTS OF DISSEMINATION. It is clear that the behavior of the pycnosporos on being discharged places them at the disposal of wind, rain, and possibly insects, depending largely on the conditions of moisture. Halsted (1892) states that "the germs pass . . . through the air or by means of the various insects that visit the fruits, especially those with broken surfaces due to partial decay." A similar opinion is expressed by Sturgis (1894). Lamson (1902:76) states that the spores are easily floated in slight currents of air, while Bethune (1909:29) and McCready (1910) attribute dissemination to the wind.

The writer has observed numerous cases of the disease in isolated situations. In some orchards there was abundant leaf spot but no cankers were on the trees. Here the wind probably acted as the agent, carrying the spores from plants outside the orchard. That the rain washes the spores to the foliage is shown by the cone-shaped area of infections beneath cankers and diseased fruits.

Insects are no doubt agents in the dissemination of the organism. The gelatinous nature of the spores renders them sticky and they may adhere to the feet of insects. In June, 1913, the writer found spores on the feet of the rosy apple aphid (*Aphis sorbi* Kalténbach), but it is his opinion that insects are of little importance in carrying the spores. Their rôle in making openings in the fruit and bark is probably much more important.

INFECTION COURTS. The fungus shows little preference for any particular type of injury as a means of entrance. It is not able to penetrate healthy tissue of the bark and fruit, but follows other fungi such as *Glomerella cingulata* (Stonem.) S. and vS. on fruit, as noted by Alwood

(1902:257). Other points of entrance to fruit, as listed by Burrill and Blair (1901), are insect punctures, mechanical injuries, and the blossom end of the apple. These authors state also that the fungus seems to start without the aid of a wound. The writer has noted many cases in which young lesions on the apple surrounded an opening made by the codling moth (*Carpocapsa pomonella* L.). Delacroix (1903 a:140) is disposed to believe that in some cases certain insects are able to rupture the bark, especially that of young branches. He observed an abundance of *Epidiaspis piricola* (Del Guer.) Ckl. on infected areas, and is of the opinion that these insects are concerned here. Güssow (1911) states that "apples are infected through some injury (wasps, curculio, hail, etc., etc.)." Arnaud (1912) believes that there is some connection between the entrance of the fungus, and a beetle.

Observations show also that various mechanical injuries commonly serve as points of entrance for the fungus. Such injuries as limb and hail bruises may act in this capacity. Faurot (1912) states that rot occurs largely on fruits the skin of which was previously broken by spray injury and growth cracks.

Whether the healthy epidermis of the fruit is penetrated, as suggested by Burrill and Blair (1901), is open to question. The writer has never been able to infect unbroken tissues of the apple fruit. On the foliage, artificial inoculations by various investigators — Scott and Rorer (1908), Brooks and DeMeritt (1912), and others — show that the fungus can penetrate healthy leaf tissues. The author, however, has never been successful in producing leaf spot without first wounding the tissue. Infections in the bark apparently occur only through some sort of wound. Such injuries may be caused by growth cracks, as noted by Caesar (1909); by ladders and boots, in pruning and picking; by barking by the machinery, in cultivation; by props not carefully wrapped; by hail; by openings left by the careless removal of water sprouts; and in other ways. Of fifteen young cankers observed by the writer on a single tree, ten had their origin in openings left by the removal of suckers. The writer has observed cases in which the fungus had followed the rust fungus, *Gymnosporangium juniperi-virginianae* Schw., on apple twigs. Scott and Rorer (1909:11) suggest that it may follow *Phyllosticta solitaria* E. & E. on apple buds. The writer has frequently isolated the fungus from lesions caused by the blotch fungus (*P. solitaria*) on apple fruits sent from Indiana. As previously noted, the fungus frequently follows fire blight and winter injury. Morse and Lewis (1910) state that in Maine orchards much of the disease that was called canker had its origin in frost spots of 1906-1907, and that so far as investigated the cankers of fruit trees in Maine orchards had their origin in wounds.

PYCNOSPORE GERMINATION (Fig. 29). The pycnospores usually germinate readily in tap or rain water. The time required for the process varies considerably, depending, no doubt, on the age of the spores. If they overwinter, the question of their longevity arises. As a rule sexual spores are regarded as short-lived, but it is not so in the case of this fungus. Duggar (1909:353) says: "The spores seem to retain their vitality for a considerable period of time, having been germinated after being stored for a year in the laboratory." The writer has found that spores two years old or older may germinate in tap water after twenty-four hours. Younger spores ordinarily germinate within five or six hours, but they may produce a tube after three hours. Spores which are dark brown in color, often septate, and having an older appearance, require more than twelve hours for germination.

Usually one or two tubes emerge from a spore at or near the end; germinations also occur at the side. The developing hyphæ in culture occasionally form microconidia, or secondary conidia, near the growing point of a hypha; these have been mentioned by Delacroix (1903 a:139), who states that they do not develop

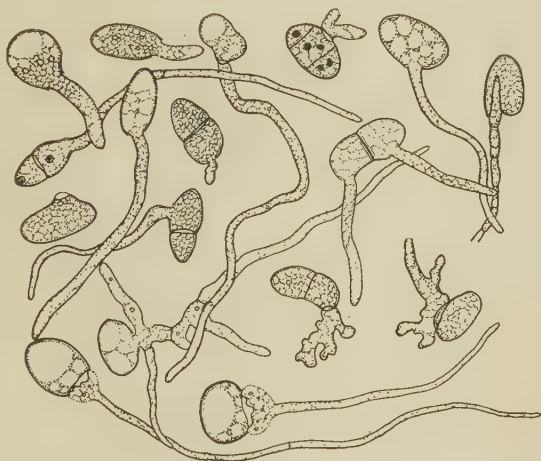


FIG. 29. TYPES AND VARIATIONS OF PYCNOSPORE GERMINATION

further. The writer has germinated them in tap water. In some cases peculiar types of germination occur, short, stunted tubes being developed. In other cases the process is entirely inhibited, and in certain of these cases the laying down of a cross-wall takes place instead. In one observation notes were made as follows:

Spores one-celled when collected (May 13, 1913). Placed to germinate in tap water and after twenty-four hours the two-celled spores had not germinated; the one-celled spores had developed tubes about 30μ long. After forty-two hours some of the two-celled spores developed tubes about 175μ in length, whereas the germ tubes of the one-celled forms were about 500μ long.

Again, spores placed to germinate, instead of producing a germ tube, after several days developed a septum. Another peculiar behavior of the spores is that they may fuse in pairs. Delacroix (1903 a) describes a peculiar type of germination of young and hyaline pycnospores in a

solution of 2.5 per cent of glucose and 1 per cent of peptone. No cross-wall was developed. After the third day the wall broke and the contents emerged, forming a bud on the surface of the spore. This spherule may attain a diameter of from 35 to 40 μ ; its further development was not followed by Delacroix. The writer has observed similar behavior of pycnospores, except that the swollen parts finally developed a germ tube. This took place in tap water. In some cases older spores burst and fail to send out a germ tube.

The effect of low temperatures on pycnospore germination was noticed in the spring of 1913 in connection with infection experiments. On May 15, 1912, spores in drops of tap water on a glass slide were placed in a petri dish, plenty of water was supplied to prevent drying out, and the culture was placed out of doors, where the temperature ranged between 8° and 10° C. A second culture was kept at room temperature (21° C.). No germinations occurred outside, but the cultures kept in the laboratory at 21° C. gave normal germinations. On May 12, 1913, the minimum temperature was 9° C., the maximum 15.5° C. All spores out of doors failed to germinate at these temperatures, while those at 21° C. gave normal germination. On May 13, 19, and 20, 1913, when the maximum temperature was 15.5° C., similar results were obtained, except that in one culture on May 20, at 15.5° C., a very low percentage of germination was observed.

This indicates that in most cases a temperature of 15.5° C. is unfavorable for germination, and that below that point germination fails. Delacroix (1903 a:139) states that mature spores germinate after forty-eight hours at a temperature of about 16° C. (60.8° F.).



FIG. 30. STAGES IN THE GERMINATION OF ASCOSPORES

ASCOSPORE GERMINATION (Fig. 30). The ascospores germinate readily in tap water and potato agar. The time required for the process is from six to twelve hours. In some cases a septum is developed in the ascospore during germination.

INCUBATION PERIOD. The period of incubation on apple bark, as stated by Potebnia (1907:16), is about four days. On foliage it is about five days, according to the observations of Scott and Rorer (1908:50-51). Inoculations made by the writer on bark show that the time between

inoculation and the first sign of the disease is from two to seven days, varying with the strains of the fungus used and the meteorological conditions. The average is four days. On fruit, discoloration appears after from twenty-four to forty-eight hours.

PATHOLOGICAL HISTOLOGY. *Fruit.*—If a section of an apple fruit is made perpendicular to the surface, the cuticle, epidermis, hypodermis, cortex, and scattered vascular bundles are in evidence. The epidermis is composed of a single layer of rectangular cells, the outer walls of which are strongly thickened by a waxy infiltration to form the cuticle. Immediately below the epidermal cells is the hypodermal parenchyma, the cells of which are distinctly different from those more deeply seated. They are compactly arranged, comparatively small, and oblong, with the greater diameter parallel to the surface. They contain the coloring matter of the fruit. There is a gradual transition from these cells to the large isodiametric cells that make up the mass of the apple tissue. The veinlets come from ten main veins and by continued branching the bundles become scattered, being finally lost in the cortex.

There is a sharp line of demarcation between the healthy and the diseased tissues (Plate XII, 2); this is especially noticeable in the hypodermal parenchyma. The coloring matter is abundant in the normal cells of the hypodermis; at the junction of the two regions the coloration is lost very abruptly and the tissue is a distinct brown. All the affected region is brown and the discoloration in the cortex extends beyond that in the hypodermis. Apparently the hypodermis is attacked along the advancing margin of the lesion from the cortex below. The mycelium of the fungus is found in advance of any apparent change in the normal color, and is found in the cortex first, at a point several cells in advance of the affected hypodermal cells. The hypodermis appears to be undermined. The walls of the cells in this region are greatly thickened; the process is apparent within a week after infection, and when the apple becomes mummified the lumen of the cell is nearly closed. Dandeno (1906) states that there is a production of cellulose in the cell wall of the apple in the course of its decomposition. Starch is also produced in the cells invaded by the mycelium of the fungus, but with the thickening the starch grains disappear. The excessive thickening is regarded by Dandeno as resulting in the preservation of the mummy.

The mycelium is usually, if not always, intercellular. In thick, free-hand sections strands may be found crossing the cell cavity, but cell-wall penetration has not been observed. Frequently small threads appear to pass into the cell of the host from the parent branch which is in the intercellular space, but no opening in the host-cell wall has been seen.

Such hyphae are regarded as being intercellular, merely giving the appearance of an intracellular habit because of the thickness of the section;

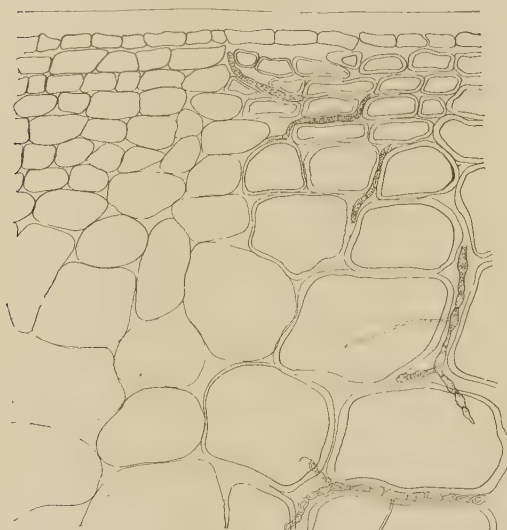


FIG. 31. HISTOLOGICAL CHANGES IN THE FRUIT OF APPLE

Showing appearance of healthy tissue at left and diseased tissue at right, and the mycelial relationship to the host cells

in thin, microtomed sections the threads are found between the cells. In certain cases the hyphae appear to be within the cells, but one may mistake a large intercellular space for a cell lumen. Dandeno (1906) states that the mycelium is intercellular, but that small threads enter the cells and even pass through them (Fig. 31).

Leaves.—The lesion produced on the leaf is largely necrotic. The cells are brown, collapsed, and obviously dead. The average thickness of the normal apple leaf is about 142μ , whereas that of the diseased area is about 61μ (Fig. 32).

The epidermal cells of the affected tissue are flattened and bear little resemblance to normal epidermis. The palisade cells maintain their relative position but are considerably shortened. The cells of the spongy parenchyma are shriveled and irregular in form (Fig. 32).

In some cases the lesions are limited by a vein, and, although a small vein may mark the extent of the diseased area, the larger veins more frequently act in this capacity. In cases in which the edge of the spot does not fall at a vein, a plate of cells surrounds the lesion and limits, for a time at least, the extent of the fungus.

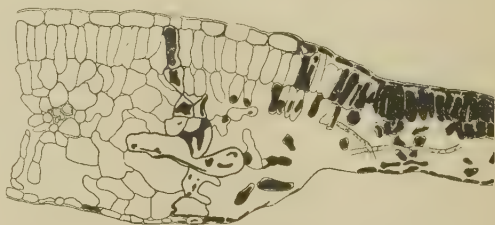


FIG. 32. HISTOLOGICAL CHANGES IN DISEASED LEAF TISSUE

Showing healthy and diseased tissue. The beginning of the suberized layer, represented by heavy-walled cells in a line from epidermis to epidermis, should be noted

The structure of the leaf at the margin of a spot is very different from either the healthy or the dead parts. The process of differentiation apparently takes place in considerable advance of the fungus. In some stained sections

a row of cells with dark-stained walls is seen in the leaf (Fig. 32). They are arranged in a direct line from the upper to the lower epidermis. This involves the palisade cells and the spongy parenchyma, the latter tissue now being composed of more densely packed, but large, cells. With the advance of the fungus this layer increases in size and number of cells until the diameter is increased over that of the normal part. An additional layer of palisade cells may be developed in this region, but in a late stage the entire mesophyll becomes densely filled with large, irregularly shaped cells. The elongated palisade cells are completely changed and become isodiametric in form. The apparent stimulation results in hyperplasia and metaplasia of the palisade cells and in hyperplasia of the spongy tissue (Fig. 33).

The diseased cells give a test for suberin with chlor-iodide of zinc and with cyanine-glycerin. Certain stages in the development of the leaf spot show discoloration of the epidermal cells up to the suberized layer only. Later, however, the epidermal cells are affected beyond this region, as evidenced by their loss of normal size and color. It appears that penetration of the temporary layer is accomplished by the fungus invading the epidermal cells and thence advancing into the healthy tissue. At any rate the mycelium is found in the epidermal cells in this region. The alternate processes of the formation of this layer of tissue, and the subsequent invasion of the tissue beyond the suberized layer by the parasite, give rise to the concentric rings previously described.



FIG. 33. HISTOLOGICAL CHANGES IN DISEASED LEAF TISSUE

Showing the reactions of the host along the margin of the lesion. Metaplasia and hyperplasia are exhibited in the mesophyll

Bark.—The tissues of the normal apple stem represent the condition found in a typical dicotyledonous plant. In the center is the pith, radiating from which region are alternate medullary rays and fibrovascular bundles. Outside these is a cylinder of secondary cortex, which is in turn surrounded by a cylinder of thick-walled cortex (probably primary in nature) and one of cork or periderm. In older stems the epidermis is not present. The secondary cortex is composed of several layers of phloem, in turn made up of hard, or lignified, sclerenchyma fibers, sieve tubes, companion cells, and phloem parenchyma. In a longitudinal section the medullary rays are prominent and are perpendicular to the periderm. In the secondary cortex these rays are connected by rows of

phloem parenchyma which are oriented at right angles to the direction of the medullary rays. These phloem parenchyma cells are rectangular and similar to the medullary ray cells; the arrangement of the former results in the noticeable stratification of the secondary cortex.

The material for comparative study of healthy and diseased tissues was usually taken so that both areas would appear in the same section. Cankers from natural and artificial infection were fixed in Gilson's fixer



FIG. 34. HISTOLOGICAL CHANGES IN DISEASED WOOD

Two apple twigs, showing cankers as they appear on surface. The specimens on the right are the same twigs, with bark removed to show the streak

or in chrom-acetic acid, hardened in the usual manner, and finally imbedded in either celloidin or collodion. Sections made from such material, as well as from fresh tissue, were cut with a desk microtome and stained with the following stains: safranin and methyl blue; safranin and methyl green; phloroglucin; and a chlorophyll solution.

In the normal tissues the lignified and suberized tissues—that is, cork and hard sclerenchyma fibers—are stained red with safranin, whereas

the cellulose tissues, cortical and medullary, are colored blue with methyl-blue and unstained with methyl-green. The woody parts stain red with phloroglucin. In the diseased part there is a very prominent general brownish deposit, located chiefly in the medullary ray cells, the thick-walled cortical parenchyma, and the phloem parenchyma. Such cells are not stained by any of the stains used. The sclerenchyma fibers and the cork are colored red by safranine, whereas suberized cork cells are made green with a chlorophyll solution. Diseased wood shows a test for lignin phloroglucin.

The more striking external symptoms of the canker noted are the discoloration of the bark, a crevice at the margin of the lesion, and a sinking of the tissues. It has been noted elsewhere that the organism penetrates the wood to a limited extent only, so that the more notable changes occur in the bark. The canker is sometimes superficial, the attacks of the organism being confined to the cortical tissues. Attacks on the wood of old limbs are not frequent, but on twigs the wood is subject to common invasion by the parasite. In cross and longitudinal sections the first and the second, and sometimes the third, layers of wood, and even the pith, are discolored. Closer examination shows the mycelium to be very abundant within the vessels of the xylem and in the woody parenchyma. In this region the characteristic brown deposit is found, but is located chiefly in the cells of the medullary rays and the wood parenchyma. Inoculations on young apple trees in the greenhouse with the ascospore strain (no. 82, from apple) show that

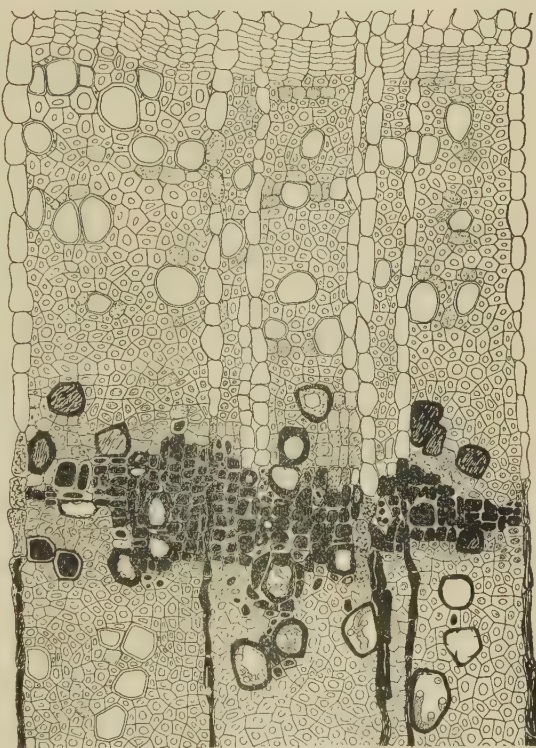


FIG. 35. HISTOLOGICAL CHANGES IN DISEASED WOOD

Cross section of part of apple twig, showing brown deposit in wood fibers and wood parenchyma cells. Mycelium is also shown in the xylem ducts, but it should be noted that none is found in other woody elements

the mycelium to be very abundant within the vessels of the xylem and in the woody parenchyma. In this region the characteristic brown deposit is found, but is located chiefly in the cells of the medullary rays and the wood parenchyma. Inoculations on young apple trees in the greenhouse with the ascospore strain (no. 82, from apple) show that

there is a streak developed in the outer layers of wood (Fig. 34), just as in the twig blight on chestnut oak, *Quercus prinus*, as reported by Ingram (1912) and noted subsequently by Rankin (1914). The streak is due to the discoloration of the cells, not to the presence of the mycelium (Figs. 35 and 36). One has only to examine longisections through the streak to be convinced that the hyphal threads do not grow in strands and are not otherwise arranged so as to give such an appearance to the tissue.

In the case of the more superficial cankers the ingress of the fungus is cut off from the healthy tissue by the development of a cork layer (Fig. 37). Such lesions reveal in section the presence of a layer approximating the normal periderm, with which it is continuous and which reacts the same

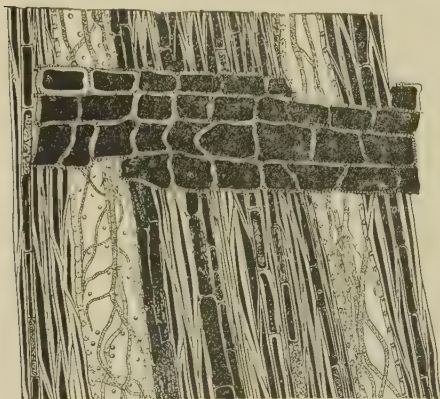


FIG. 36. HISTOLOGICAL CHANGES IN DISEASED WOOD

Longisection of a part of apple twig, showing brown deposit in woody elements. Mycelium is again to be seen in the xylem ducts

with safranin and with a chlorophyll solution. These cells in their final state are suberized.

The layer originates by the division of cells of the cortical parenchyma. The sclerenchyma fibers are not changed. If the layer comes in contact with a group of sclerenchyma fibers it is interrupted. The more recently affected cells—that is, those nearest the margin of the lesion—show a reddish tinge with safranin, indicating slight suberization throughout the region. Later, evidence of the cork layer is found just beyond the infected zone. Walls

are laid down to form rectangular cells characteristic of the final cork layer and of the normal periderm. At this time they do not take the safranin, indicating that suberization has not begun. Such sections stained with chlorophyll solution also show no suberin reaction.

A later examination of the marginal layer between healthy and diseased tissue stained with safranin will reveal three distinct and characteristic zones, as follows (enumerating outward): a red layer of three or four suberized cork cells; a colorless layer of about two non-suberized cells, rectangular; and a third layer of about two smaller cells of the same shape bearing a brownish deposit, making a distinct brown line. Many slides show the reverse relation with respect to the suberized and cellulose layers; the colorless layer, composed of cells with cellulose walls, may lie next to the diseased tissue, and the cells with suberized walls next to the brown line.

This raises the question as to which cells are suberized first. The assumption is that those cells nearest the diseased zone are suberized first. This would be expected, in such a case, where response to injury is made by the host. But this scarcely explains the cases in which the colorless layer borders the affected tissue. In these cases, however, the brown line is not so distinct as described above, and often is not in evidence; so that this may stand as a younger stage in the formation of the cork layer. The cells of the suberized layers do not react alike when stained with safranin. A row of cells in the center is the darkest, the color shading off on both sides, perhaps indicating the amount of suberization.

The majority of the cells of the layer are densely granular, are thin-walled at first, and possess large nuclei. These have the characteristics of rapidly dividing cells.

A section through a canker having a crevice at its margin shows that the break follows the brown line. The dead tissues on the one hand shrink, while the living, normal part increases in diameter by growth, exerting tension on all tissues of the bark, and the break results. It appears that the cells making up the brown line are the weakest, and thus they mark the line of separation of the diseased from the healthy tissue.

Along the marginal layer diseased pockets occasionally are formed which extend into the healthy tissue. Such areas are always in the region of a group of sclerenchyma fibers. A cork layer surrounds the pocket. Cross sections may be cut so as to include only a portion of one of these pockets, making them appear as internal, separate infections. Serial sections, however, always reveal their connection with the originally infected tissue.

In the diseased region are found the same stratified layers as mentioned in the survey of the normal secondary cortex. But in the affected areas

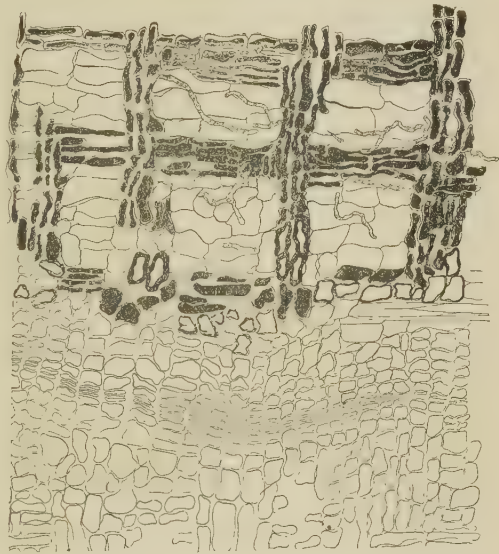


FIG. 37. HISTOLOGICAL CHANGES IN DISEASED BARK

Showing brown deposit in the medullary ray cells and phloem parenchyma, which cross at right angles resulting in a stratified appearance in the phloem. Below the diseased region is seen the cork layer

both the cells of the medullary rays and the phloem parenchyma stand out very prominently, being filled with the brownish deposit. The remainder of the old phloem elements, the sieve tubes, companion cells, and sclerenchyma fibers, are not discolored at all. (Fig. 37.)

The brown mycelium of the fungus is found very abundantly throughout the diseased area. It is intercellular, except when it encounters the xylem and the hard sclerenchyma fibers; it is not easy to say just what the relationship is with respect to hard sclerenchyma fibers. It is noted elsewhere that the hyphæ are found within the tracheal tubes. The threads for the most part pass up and down the stem. This is in accordance with the external symptoms of a lesion. It has been stated previously that where the cork layer encounters a group of sclerenchyma fibers it is interrupted, and the fungus breaks through the barrier as laid down by its host. There is no evidence that the suberized cells are ever penetrated. Mycelium is found advancing through the layer at points where the sclerenchyma fibers cross it, a discoloration precedes the hyphæ, and almost before the threads get into the healthy tissue the latter is changed in its normal color. Very soon after is found evidence of a secondary cork layer, which usually branches from the primary layer at some point beneath the point of secondary penetration. This extends around the newly affected region, finally passing above to the normal periderm. Repetition of this process, accompanied by the formation of crevices at each successive cork layer, results in the concentric lines or cracks so characteristic, externally, of the lesion. The drying out and death of the cells results in their collapse, and the affected part shrinks.

CONTROL

BLACK ROT

EXCLUSION BY LEGISLATION

As previously noted (Evans, 1910), the British Government at Cape Colony has legislated against black rot. Importers are warned that, under a government notice of 1908, all consignments of pomaceous fruits found infected with this organism to the extent of one per cent and upward will be destroyed on arrival at the Colony or returned to the consignor.

SPRAYING

It was suggested by Sturgis (1893 b) that spraying in August and September would prevent black rot of quince. The following year the same author (1894) found that a 0.03-per-cent solution of copper sulfate is fatal to the fungus. More recently Waite (1906:19) recommends the same treatment as for apple scab. Wolf (1913) concludes from experiments conducted in Alabama that bordeaux 4-4-50, applied as follows, will be effective: the first spraying, about July 15, when the disease is just

appearing; the second, two weeks later. This schedule gave satisfactory control, the sprayed fruits showing less than one per cent diseased on certain varieties. Control was less complete on Black Ben Davis, which exhibited from ten to fifteen per cent of black rot. Lime-sulfur was found to be wholly ineffective under southern conditions in 1912.

It should be remembered that frequently infections follow the work of the codling moth, and, as stated by Clinton and Britton (1910), the control of this insect lessens the amount of rot starting at such centers. The work heretofore described indicates that certain insects carry the spores; it is therefore important to consider the control of these pests.

HANDLING OF FRUITS

It is apparent from the life history studies that spores of the black rot organism are present in the orchard at picking time and are carried into storage. It has also been learned that the fungus effects penetration only through injured tissue. Consequently one factor in obtaining apples of good keeping quality is the elimination of mechanical and other injuries to the fruit; the occurrence of black rot in storage is undoubtedly connected with the handling methods in use in the orchard.

STORAGE

It has been found by Lamson (1902:81), and subsequently by Eustace (1908), that the temperature of the storage room should be about 31° to 34° F. (-0.5° to 1.1° C.). Higher temperatures allow growth of the fungus. It is important to note that when apples are stored in barrels, about one week is required for the temperature of the center of the receptacle to become equal to that of the storage room.

LEAF SPOT

SPRAYING

It seems that Alwood (1892) was the first to advocate the use of sprays for leaf spot. He recommends two applications, as follows: the first, just as the petals have fallen from the apple, using bordeaux mixture 4-5-50; the second, about twenty to twenty-five days later. The recommendations of later writers differ in number of applications and in type of fungicide. It is very apparent that the number of sprayings in a given year will depend on the character of the season. Ordinarily two or three applications are necessary, according to Brooks (1909, and 1912, a and b) and others. In certain seasons of considerable rainfall additional sprayings may be necessary.

As previously noted, in some districts at least the leaves are infected shortly after they unfold from the bud, and infections may continue throughout the spring according to Brooks (1909:124). Later Brooks and De-Meritt (1912:188) conclude that the period of infection extends throughout

the middle of the summer. The number of applications then to be made will depend on the character of the season and the abundance of spores present.

In some sections of the country where apple scab also is to be combated, the regular scab sprayings have been generally recommended as sufficient. These are given by Wallace (1913:589-590) as follows: the first, when the blossoms show pink; the second, after the blossoms fall; the third, two or three weeks later. If later scab sprayings are necessary, the leaf spot will be controlled. Scott (1906:33) states that the disease may be controlled in connection with the treatment for bitter rot; for the latter disease he recommends from four to six applications of bordeaux mixture, made at intervals of two weeks beginning about six weeks after the trees blossom.

Apparently bordeaux mixture has been most commonly employed for leaf spot. Brooks (1912 b:15) maintains that it is the most effective fungicide for apple diseases, but points out that an objection to its use lies in the fact that spotting of the foliage and russetting of the fruit are likely to occur if showers follow its application. The spots produced on the leaves resemble those caused by the fungus. For leaf spot alone, Brooks (page 8 of same reference) finds that self-boiled lime-sulfur best holds the disease in check.

Lime-sulfur is regarded by Brooks (1912 b) as a satisfactory substitute for bordeaux, and in a later publication Brooks and DeMeritt (1912) show that commercial lime-sulfur at a strength of one gallon to twenty-five gallons of water reduced the infection from about 95 per cent to 26 per cent. When used at a strength of one gallon to fifty gallons of water, the lime-sulfur was found to be less effective. Brooks considers this fungicide about as efficient as bordeaux, and, because of the injury from the latter, lime-sulfur would appear the more desirable.

CULTIVATION

Brooks and DeMeritt (1912) have observed marked contrast between the amount of infection in sod and in cultivated orchards. They record the former as showing 0.79 spot per leaf, whereas in the latter there was only 0.47 spot per leaf. They say (page 189 of reference cited):

The trees had been treated alike in every other respect and were of equal vigor when the experimental work was begun; it was, therefore, evident that cultivation had reduced the disease almost one-half. This reduction was probably partly due to the fact that the leaves were plowed under on the cultivated plots, but the lack of general vigor in the trees on the sod plots was apparently partly responsible for the difference.

CANKER

HISTORICAL AND INTRODUCTORY

The control of cankers has been a matter of consideration for some time. Nearly three centuries ago Parkinson (1629:550) recommended surgical

methods together with a wound dressing of vinegar. Similar advice is given by Harrison (1823:342), who suggests a dressing of soot, water, and train oil. He recommends drainage of the soil in severe cases.

In more recent times, beginning with the appearance of the work of Paddock (1899 b), the recommendations are all essentially of the same nature. The employment of the common methods of orchard management — cultivation, fertilization, pruning, and spraying — is recommended, in order to promote general vigor. Keeping the trees in good growing condition is claimed to be essential (Warren and McCourt, 1905). Spraying to protect the bark is frequently recommended (Bethune, 1909:30, and others), while scraping the bark and applying a wash is suggested by Paddock (1899 b:190) and others. Pruning of diseased limbs and the growing of a new top is being practiced by some growers.

The control measures more commonly employed by the growers of New York State are pruning and spraying; other measures, as determined by circular letters and personal observation, are surgery, cultivation, fertilization, and mulching. The success of these methods varies and seems to depend on the vigilance with which the grower pursues the disease.

SURGICAL METHODS

PRUNING. In pruning for the control of canker, two methods may be employed: the limb may be cut from the tree entirely, or the cankered bark may be removed. In either case a wound will result and the application of a dressing becomes essential.

Removal of limbs.—The question frequently arises, when shall only the canker be cut out, and when is it necessary to remove the limb? No general rule can be laid down, but each case must be examined carefully and procedure taken accordingly. If the limb is large and productive, its removal should be postponed. This is commonly the practice. But to wait until the limb is not producing satisfactorily usually means that the canker will aid in bringing the branch to destruction. In such cases it is advisable to prevent the loss by eradicating the cankered spot by surgery.

If the limb is not producing, whether large or small, its removal for the purpose of eliminating the fungus is the alternative. The cut should be made so that another limb, or water sprout, may be allowed to grow in the approximate space left by the part removed. This method of treating the New York apple tree canker is employed in certain orchards along the Lake Ontario belt in this State. One grower is very successful in this measure of control. This, with protection from new infections by careful spraying of the entire tree — trunk and limbs — renders even the highly susceptible Twenty Ounce variety practically free from canker.

Grafting of stubs left by the pruning of the affected parts of limbs is occasionally practiced. This may be justified in certain cases, although as a rule it should be supplemented in the main by the method just described.

Removal of diseased bark.—The cutting out of cankers is a method to be employed when the grower is satisfied that the value of the limb warrants it. An attempt to remove all kinds and sizes of cankers from an infested orchard without regard to such a consideration is likely to result in the discouragement of the orchardist with the whole undertaking. The equipment necessary for use in the removal of cankered bark consists of a drawshave and a farrier's knife. The limits of the diseased area are ordinarily determined by making an external examination of the canker. Where this method is not reliable, small bits of the outer bark may be removed, following the line of the discoloration until the limits are determined. Similarly the depth of the canker is defined.

The shape of the cut will vary somewhat with that of the canker to be removed. So far as possible, the wound when finally finished should be lenticular in form. This will facilitate callus formation. If the wound is rectangular the upper and lower edges heal more slowly. The edge of the wound should be perpendicular to the long axis of the limb, for cuts made at a slant will result in a certain amount of dead cortex, which is undesirable from the standpoint of new infections. A possible exception to this method of trimming the margin is to be found at the lower end of the wound. Here the edge should be slanting enough to permit drainage of moisture.

WOUND TREATMENT. It is frequently advised that the wound should be disinfected and protected. The latter is certainly commendable practice, but whether the former is necessary will depend on the nature of the wound dressing.

Wound disinfection.—If the dressing itself is a disinfectant, a special disinfectant will not be necessary. In case one is needed, mercuric chloride at the usual strength (1-1000), or copper sulfate (1 ounce to 1 gallon of water), is most commonly used.

Wound protection.—The necessity of a protective covering for wounds is twofold: to check the weathering of the wound, and to prevent the growth of bacteria and fungi. It follows, then, that the fundamental requirement of a wound dressing is that it should be a preservative and a preventive. Briefly, then, the dressing should have antiseptic qualities, and should be fluid, reasonably inexpensive, and easily prepared and applied; it is essential that it should give complete covering; it must be impervious to air and water, must be durable, and must not injure nor kill the tissues nor interfere with the healing process.

The preparations now most commonly used are paint, tars, and asphaltum. In some cases commercial tree paints are employed. It is generally agreed that paints are an inefficient covering, whereas asphaltum once applied gives the desired protection. Asphaltum, however, is more difficult to apply. This is particularly true if the asphaltum used is rendered liquid by heat; if it is dissolved in gasoline it is more easily prepared and hence more available. The combination of asphaltum and gasoline has been applied rather extensively in the orchard of Fred Hazleton, at Leroy, New York, and from all appearances is commendable.

The writer has used coal tar for the past three years with good success. This is a residual tar derived in the manufacture of artificial gas from coal. According to Lunge (1909), tars may vary even from the same materials, depending on the temperature used in the distillation, the shape of the retort, and other factors. The use of coal tar as a wound dressing has been recommended to growers of the State, and some have complained of injury to the healthy tissue from its use while others report it as an appropriate material. Many cases of injury have been found to have resulted from the use of creosote, but not from coal tar. The pruner must distinguish between the two materials. The writer has never seen any cases of injury from coal tar on apple trees, and it has been used successfully on peaches by Jehle (1913). It is interesting to note a quotation from Des Cars as given by Bailey (1907:111-113):

The application of coal tar should not be made except with considerable caution in the treatment of wounds on drupaceous fruits (cherries, peaches, plums, etc.), and especially on the plum tree. It has often been observed that the bark of fruit trees of this class has suffered from the application of coal tar. This is not the case, however, with pome-bearing trees (apples, pears, etc.); to these coal tar may be applied with perfect safety.

Card (1897:9) reports experiments in pruning in which he tested various materials for protecting wounds. He says of coal tar: "Coal tar, however, seems to have been a positive hindrance to the healing process, not one wound having been reported as healing extremely well, while the majority are reported as healing only fairly well." As a comment on this remark, Bailey (1907:113) says: "It is not said, however, whether the tar injured the tissues, or whether the apparent results may not have been due to the position and character of the wound quite as much as to the dressing. In my own experiments . . . tar did no damage."

In view of the complaints made of injury from the use of coal tar, it occurred to the writer that this substance varied sufficiently in different parts of the State to account for the injury, if any ever occurred. Samples were obtained from the gas plants in the following cities in New York: Syracuse, Owego, Batavia, Rochester, Ithaca, Lockport, Buffalo, Albion, and Geneva. These samples were applied to wounds of mature apple

trees on the farm of Dr. Johnson, at Leroy, New York, in August, 1912. Examination at intervals during the growing seasons of 1912 and 1913 showed equally good healing and no injury. Another orchard, near Batavia, New York, owned by Chapin & Son, has been extensively treated with coal tar, with results similar to those just described. The writer has applied coal tar to Northern Spy, Baldwin, and Hubbardston apples in an orchard at Byron, New York, and no detrimental effects have been observed. In some cases the wound has been disinfected by the use of mercuric chloride (1-1000), but no difference in the efficiency of protection was observed between wounds so treated and those not disinfected. The writer feels safe in recommending the use of coal tar without previously disinfecting the wounded surface.

The cost of canker treatment — that is, the removal of diseased bark and the application of a dressing — is not an easy matter to determine. Where it is done extensively the grower usually does the work along with the regular pruning, so that the cost of canker treatment alone can hardly be separated from that of the whole operation. In an apple orchard at Leroy, New York, careful work was done in 1912 by A. S. Davis. The orchard contained 950 forty-years-old trees. The orchard had been neglected for several years, and dead limbs, cankers, collar rot, and heart rot were abundant. Mr. Davis furnishes the following figures:

Cost of trimming.....	\$407.90
Coal tar, 40 gallons, at 20 cents a gallon.....	8.00
Corrosive sublimate.....	.75
Applying tar	30.00
Removal and destruction of brush.....	54.70
Total	<u>\$501.35</u>

The following data are taken from a similar orchard at Batavia, New York:

Miscellaneous data	
Number of trees.....	360
Age of trees.....	30 years
Cost	
Labor, 348 hours, at 25 cents an hour.....	\$87.00
Coal tar, 10 gallons, at 15 cents a gallon.....	1.50
Corrosive sublimate.....	.50
Total.....	<u>\$89.00</u>

It is seen that the average cost of the work in the Leroy orchard is about fifty-two cents a tree. It must be borne in mind that the orchard

had not been pruned in several years, which accounts in part for the high cost of the work. In the Batavia orchard the average cost is approximately twenty-five cents a tree. These figures do not represent the cost of treating the cankers alone; this process itself would be considerably less than either of the above figures.

WOUND HEALING. *Wound cork.*—According to Hartig (1894:225), whenever the living phellogen is injured a new zone of phellogen, or cork, which is continuous with the cork layer along the edge of the wound, is formed from the uninjured cells which are situated deeper in the cortex. The cortical parenchyma, which lies beneath the periderm, possesses sufficient power of cell division to enable it to keep pace with the increasing thickness of the stem. But in the case of the wound its reproductive capacity is confined to the development of a periderm close beneath the surface of the exposed tissues. Its formation does not depend on the season of the year, but it may be formed even in winter.

Wound wood.—Hartig (1894:228) states that wood exposed by a wound has the power of producing new cortex and new wood when the cambium is active and when the cambium layer and young wood are protected from drought. In such a case, regeneration of the covering layers is effected. The cambial region consists of embryonic bast and wood, which is capable of growth and ultimately of a certain amount of differentiation. The wood thus formed is termed wound wood.

Callus.—Callus may be developed when the cambium has dried up or when it is absent from the surface of the wound. Its formation proceeds from the edge of the wound, beginning in the cambium. Hartig (1894:231) states that it is a purely mechanical process and results from the reduction of the bark pressure on these tissues. There is always a certain amount of tension in the cortical mantle, whereby a considerable pressure is exerted on the cambium. Should this pressure be locally reduced by a wound's reaching the wood, the processes of cell division and growth are accelerated not only along the edges of the wound but also at greater distances. The callus cushions advance from the edges of the wound, finally coming in contact and coalescing. This coalescence is retarded if the callus is clothed at an early stage with dead bark.

It has been noted that wounds made in cutting out cankers should be pointed in order to permit rapid healing. In this connection Hartig (1894:232) states that the formation of callus proceeds more vigorously in case of a longitudinal incision than when the incision is transverse. This is explained by the nature of the pressure by the bark in consequence of peripheral enlargement of the stem. The pressure here acts like that of a barrel hoop on the staves, and so callus develops more rapidly along the lateral margins of the wound. In this connection the question of

slitting the lower edge of the callus arises. Reasoning from the data regarding the development of the callus, it seems advisable to practice this operation each year; this prevents the callus from bunching, and stimulates it to more ready occlusion of the wound.

SPRAYING

The effectiveness of spraying for canker is a question frequently raised. It is the belief of the writer that spraying as a preventive, but not as a cure, is worthy of attention. It is true, however, that growers report cases of curing canker by spraying. The fungus mycelium is protected by the bark; hence sprays will not reach it, and eradication of the fungus from a given lesion by spraying seems highly impossible. Spraying to protect healthy bark from infections would certainly appear advisable, but the data at hand are somewhat conflicting. The writer recalls an orchard in which canker does not occur. The trees are sprayed carefully each year, according to general recommendations for apples. Some of the trees are Twenty Ounce, but they are free from the disease. The limbs are kept coated with spray throughout the summer, and as late as the middle of August these trees are still covered. In contrast to this orchard, another is recalled which is severely affected with canker, yet the trees are given the regular sprayings. The difference in these cases may be accounted for by the lack of thoroughness of the spraying in the second orchard. Since protection is the principle involved in this method of control of canker, the success of any attempts in this direction is determined by the completeness of the covering.

GENERAL CONSIDERATIONS

The destruction of rubbish about the orchard is no new suggestion. Peck (1879:21) recommends that affected fruit should be removed from the orchard and destroyed. The destruction of fallen leaves is recommended by Alwood (1892). Sheldon (1905) and others suggest picking rotted fruit before the fungus spores mature in the case of quince black rot; Sheldon adds that this might not be possible with apples because of the size of the trees. In Alabama, however, Wolf (1913), as has been previously noted, controlled the disease by spraying. The opinion is held by Brooks and DeMeritt (1912:189) that affected leaves should be plowed under, while clean cultivation is the recommendation of Reed, Cooley, and Rogers (1912:5). The removal and burning of affected limbs is advocated by Bethune (1909:30) and others.

The ability of the fungus to pass from one part of the apple tree to another only adds to the sources of inoculum, so that sanitary measures become of special importance.

ORCHARD MANAGEMENT

The value of careful handling of fruit to prevent injury has been emphasized. This is based on the principle that the causal organism is a wound parasite. The same care should be exercised with reference to the bark of the tree; injury should be avoided whenever possible. Injuries to bark are likely to result from cultivating implements and harness, the careless handling of ladders while picking, and climbing over the trees with rough-soled boots. The importance of guarding against such orchard practice lies in the fact that cankers begin in just this sort of place:

It has been mentioned that the fungus follows winter injury. As a protection against winter injury, Reddick (1912:37) advocates early plowing in the spring, and cultivation to give the trees the advantage of conserved moisture; he recommends that cultivation should cease not later than August 1, in order to start the trees into maturation. Cover crops, to take up excess moisture in the autumn, should be sown. Soil drainage in low ground, and a good circulation of air, are important considerations.

When it is desired to grow varieties that are susceptible, the canker difficulty may be obviated to a considerable extent by working over the larger limbs of more resistant varieties to the one desired. This has been done with apparent success in a few instances. The difficulties involved are that pruning must be done every year to remove all sprouts from the stocks, and that renewal of old branches cannot be effected so readily. Such a treatment also throws the bearing area higher into the air, so that in the case of erect growers, such as Twenty Ounce, thorough orchard operations are made more difficult.

RESISTANT VARIETIES

Since certain varieties of the apple — for example, Esopus and Twenty Ounce — are more susceptible to canker than are other varieties, the growing of other varieties will undoubtedly render the problem of control less difficult. Twenty Ounce, however, is one of the most satisfactory fall varieties for commercial planting in New York State. The question therefore arises, whether the orchardist should sacrifice the growing of this variety in the hope of escaping the problem of canker control. The evidence at hand indicates that if a grower wishes to raise Twenty Ounce, his success in keeping the trees free from canker will depend on his efforts. Observations warrant this opinion. It is true that, as stated by Warren and McCourt (1905), "something more than thrifty growth seems to be necessary in order to prevent the destruction of the Twenty Ounce"; so that vigor in itself should not be given too much dependence. Well-

cared-for trees of this variety are often severely cankered. It is assumed that the trees must be in a thrifty condition in order to give the best results, but the control problem does not end here, for vigor does not establish nor maintain resistance.

AN ENEMY OF THE PATHOGENE

Potebnia (1912)⁸ reports an interesting case of a fungus, *Helicomycetes Sphaeropsisidis* Potebnia, living as a parasite within the conidia of *Sphaeropsis pseudodiplodia* [= *Physalospora Cydoniae*]. Infection takes place when the host (the conidia of *Physalospora Cydoniae*) is in the Macro-phoma stage. He notes a similar case reported by Japp, in which *Helicomycetes niveus* Bres. & Japp is parasitic on *Diplodia inquinans* West., and states that in Japp's herbarium specimen all pycnospores in the infected pycnidia were killed by this parasite.

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1899 a The apple canker. Country gent. 64:88.

Briefly summarizes the works of Waite and Paddock.

1899 b The apple canker. Country gent. 64:208. Illustrated.

The illustration is a text figure, and the author contends that it is the first figure of the disease published.

1899 c Perhaps apple canker. Country gent. 64:248.

A reply to an inquiry concerning the apple injury which is regarded as caused by *Sphaeropsis Malorum*. Remedy suggested.

Alderman, W. H., Giddings, N. J., and Rumsey, W. E.

1913 Orchard spraying. West Virginia Univ. Agr. Exp. Sta. Circ. 7: 1-48, fig. 1-33.

Mention black rot, leaf spot, and canker, and suggest control measures.

Alwood, W. B.

1892 Brown spot. In Four diseases of the apple, and treatment of same. Virginia Agr. and Mech. Coll. Agr. Exp. Sta. Bul. 17:59, 62.

Describes a leaf disease and uses the name *brown spot*. Notes three successive outbreaks in a summer. Questions whether *Phyllosticta pirina* is the cause.

1893 Injurious insects and diseases of plants with remedial measures for the same. Virginia Agr. and Mech. Coll. Agr. Exp. Sta. Bul. 24:1-40. Illustrated.

The apple orchards of Virginia said (p. 24) to suffer chiefly from two foliage diseases one of which is called brown spot, attributed to the attacks of *Phyllosticta pirina*.

1898 a The leaf-spot disease of apple, *Phyllosticta pirina* Sacc., and several unrelated forms occurring therewith. Amer. Assoc. Adv. Sci. Proc. 47:413.

Records the following fungi occurring with *Phyllosticta pirina* Sacc.: *Sphaeropsis Malorum* Peck, *Hendersonia Mali*, and an undetermined species.

⁸ Translated by C. D. Sherbakoff, formerly of the Department of Plant Pathology at Cornell University.

- 1898 b On the occurrence of a yeast form in the life cycle of the black rot of apple, *Sphaeropsis Malorum* Peck. Amer. Assoc. Adv. Sci. Proc. 47: 422.

Records the discovery of a yeast form occurring in cultures of this fungus, which on isolation and reinfection on the fruit of apple produced the common fruiting bodies of *Sphaeropsis Malorum*.

- 1902 Orchard studies.—XV. The bitter rot of apples. Virginia Agr. Exp. Sta. Bul. 142: 250-274, pl. 1-4.

States (p. 257) that *Sphaeropsis Malorum* Berk. invades fruit already decaying from the attacks of the bitter rot fungus.

Alwood, W. B., and Price, H. L.

- 1902 Orchard studies.—V. Report on crab apples. Virginia Agr. Exp. Sta. Bul. 132: 3-14, fig. 1-4.

Note (p. 6) that certain varieties are especially subject to the black rot canker (caused by *Sphaeropsis Malorum*).

Arnaud, G.

- 1912 Notes phytopathologiques. 1. *Sphaeropsis pseudodiplodia*. Montpellier (France) Ecole Nat. d'Agr. Ann. 12: 5-17, fig. 1-5.

Discusses the fungus as it occurs on several different plants. Notes the variable morphology of the organism and reports the discovery of an ascmycete associated with the pycnidial form. The ascmycete is named *Physalospora Cydoniae* and is regarded as probably the perfect stage of *Sphaeropsis pseudodiplodia*.

Arthur, J. C.

- 1885 Quince rot. In Report of the Botanist. New York (Geneva) Agr. Exp. Sta. Ann. rept. 3: 372.

Describes symptoms, and proves the pathogenicity of the fungus (which he calls *Sphaeropsis Cydoniae* C. & E.) on quince fruit.

Baccarini, P.

- 1890 Note patologiche. Ital. nuovo giorn. bot. 22: 64-70.

Reports *Sphaeropsis Malorum* on pears, apples, and peaches in storage. Discusses sclerotia and pycnidial development.

Bailey, L. H.

- 1907 The healing of wounds. In The pruning-book, p. 76-132, fig. 68-110.

Gives a chapter on the healing of wounds, taking up the nature of wounds, suggestions for the pruner, dressings for wounds, making cuts.

Baldwin, C. H.

- 1912 Black rot. In Some important diseases of apple. Indiana State Entomologist. Rept. 5: 249-252. Illustrated.

Gives notes on black rot, leaf spot, and canker.

- 1914 Black rot (New York apple-tree canker and apple leaf spot). In Apple diseases. Indiana State Entomologist. Rept. 7: 150-152. Illustrated.

Describes the nature of the injury.

Bary, A. de

- 1887 Comparative morphology and biology of the fungi, Mycetoza, and bacteria, p. 1-525. (Translated by H. E. F. Garnsey and I. B. Balfour.)

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Beach, S. A.

- 1912 Black rot. *In* Spraying practice for orchard and garden. Iowa Agr. Exp. Sta. Bul. 127:50-51. Illustrated.
Black rot observed to occur on some of the summer and early fall varieties.

Beach, S. A., Lowe, V. H., and Stewart, F. C.

- 1899 Apple tree canker. *Also*, Leaf spot. *In* Common diseases and insects injurious to fruits. New York (Geneva) Agr. Exp. Sta. Bul. 170:382-384.
Describe canker, caused by *Sphaeropsis Malorum* Peck, and leaf spot, due to *Phyllosticta* spp., with recommendations for control.

Beal, W. J.

- 1898 Diseases of the apple. Michigan State Hort. Soc. Ann. rept. 27:174-183, pl. 1-4.
Discusses (p. 178) symptoms of black rot of apples, and compares it with soft rot (caused by *Penicillium expansum* Link).

Berkeley, M. J.

- 1836 *Sphaeria Malorum*. *In* Hooker's English flora, p. 257-258.
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1860 *Sphaeropsis Malorum* B. *In* Outlines of British fungology, p. 316.
Changes the generic name of the fungus from *Sphaeria* to *Sphaeropsis*.

Berlese, A. N., and Voglino, P.

- 1886 *Macrophoma Malorum* (Berk.) Berl. & Vogl. *Cited in* Saccardo's Syll. Fung. 10:197. 1892. *From* Veneto-Trentina Soc. Atti. 1886:184.
The authors divide the genus *Phoma* into *Macrophoma* and *Phoma*, the basis being the length of the pycnospores; *Phoma Malorum* (Berk.) Sacc. becoming, as they believe, *Macrophoma Malorum* (Berk.) Berl. & Vogl.

Bethune, C. J. S.

- 1909 Fungus diseases and insect pests. *Also*, Cankers on apple trees. Ontario Agr. Coll. and Exp. Farm. Ann. rept. 34:26-32.
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1910 Black rot canker (*Sphaeropsis Malorum*). Ontario Agr. Coll. and Exp. Farm. Ann. rept. 35:35-36.
States that black rot canker apparently can be successfully controlled by pruning out dead branches, cutting out cankers, and coating the bark with spray.

Bommer, E., and Rousseau, M.

- 1885 Florule mycologique des environs de Bruxelles, p. 3-353.
Sphaeropsis Malorum Berk. is listed (p. 257) on fallen apples.

Brooks, Charles

- 1907 Diseases of the apple. *In* Seventeenth and eighteenth annual reports. New Hampshire Coll. Agr. Exp. Sta. Bul. 129:267-270, pl. 15.
Records black rot and cankers due to *Sphaeropsis Malorum* Berk. as common; records leaf spot due to *Phyllosticta pirina* Sacc. and *P. limitata* Peck as serious, with little or no effect on it from spraying. States that majority of apple limb cankers are caused by *Sphaeropsis Malorum* Berk., and that few of the orchards visited did not show the disease.

- 1909 Black rot, canker, and leaf spot. *In* Some apple diseases. New Hampshire Agr. Exp. Sta. Bul. 144:123-126, fig. 20-24.

Discusses occurrence, symptoms, etiology, and control of black rot, canker, and leaf spot. Lists the following fungi as associated with these diseases: *Sphaeropsis Malorum*, *Coniothyrium pirina*, *Coryneum foliticolum*, *Alternaria* sp., and one of the Tuberculariace.

- 1912 a Black rot, canker, and leaf spot. *In* Some apple diseases and their treatment. New Hampshire Agr. Exp. Sta. Bul. 157:17-20, fig. 20-24.

Maintains that black rot does considerable damage in storage. Outlines sprayings which are said to be fairly effective for leaf spot.

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Compares different fungicides for control of leaf spot.

Brooks, Charles, and DeMeritt, Margaret

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Brooks, Charles, Fisher, D. F., and Cooley, J. S.

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Bryce, P. I.

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Bubák, Fr.

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Burrill, T. J.

- 1907 Bitter rot of apples: botanical investigations. Illinois Univ. Agr. Exp. Sta. Bul. 118:553-608.

States that *Sphaeropsis Malorum* is sometimes associated with the bitter rot fungus in cankers. The former organism said to follow the latter under Illinois conditions.

Burrill, T. J., and Blair, J. C.

- 1901 Apple fruit-rots. Illinois Univ. Agr. Exp. Sta. Circ. 37:(12 pages, unnumbered). Illustrated.

Special attention given to symptoms of black rot, caused by *Sphaeropsis Malorum*. Suggestion that another species causes canker. Discussion on second and third pages.

Butler, O.

- 1912 Report of the Department of Botany. *In* Twenty-third and twenty-fourth reports. New Hampshire Agr. Exp. Sta. Bul. 163:16-17.

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Caesar, L.

- 1909 Black rot canker of apple trees. *In* Lime-sulphur wash. Part II.—Practical and popular treatment. Ontario Agr. Dept. Bul. 177: 59-61, fig. 16.

States that on leaves and fruit the disease is seldom serious, but cankers often do great damage especially in Prince Edward County, Ontario.

- 1912 Black rot canker. *In* Our most troublesome orchard insects and diseases. Ontario Fruit Growers' Assoc. Ann. rept. 44: 22, fig. 15.

Author is convinced that the fungus follows winter injury.

Card, F. W.

- 1897 Notes on pruning. Nebraska Agr. Exp. Sta. Bul. 50: 1-10.

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Chase, W. W.

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Chester, F. D.

- 1901 a Canker in apple and pear. *In* Pear blight and pear canker. Delaware Coll. Agr. Exp. Sta. Bul. 52: 6-8, fig. 4-7.

States that twigs and branches bearing pycnidia of *Sphaeropsis Malorum* Peck are sources of infection.

- 1901 b Canker in the apple and pear. *In* Report of the Mycologist. Delaware Coll. Agr. Exp. Sta. Ann. rept. 12: 43-46, fig. 4-7.
(Same as 1901 a.)

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Clement, F. M.

- 1913 Winter injury in orchards. Quebec Soc. Prot. Plants from Ins. and Fung. Dis. Ann. rept. 5: 24-26.

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Clinton, G. P.

- 1902 Black rot, *Sphaeropsis Malorum* Berk. *In* Apple rots in Illinois. Illinois Univ. Agr. Exp. Sta. Bul. 69: 192-193, pl. B, fig. 2.

Sphaeropsis Malorum Berk. regarded as one of the chief causes of rotting of apples in market.

- 1904 Black rot, *Sphaeropsis Malorum* Pk. *In* Report of the Botanist. Connecticut (New Haven) Agr. Exp. Sta. Ann. rept. 27: 298, 342, 352, pl. 11, a.

Black rot regarded as one of the commonest and most universal diseases of the apple. Noted also on pear and quince.

- 1907 Winter injury and canker, *Sphaeropsis Malorum* Pk. *In* Report of the Botanist for 1906. Connecticut (New Haven) Agr. Exp. Sta. Ann. rept. 30:310-311, pl. 17, a.

A peculiar limb disease of the apple is doubtfully attributed to winter injury and *Sphaeropsis Malorum*.

- 1915 Notes on plant diseases of Connecticut. *In* Report of the Botanist for 1913. Connecticut (New Haven) Agr. Exp. Sta. Ann. rept. 38 (1914):1-29. Illustrated.

Black rot noted on stored apples (p. 5).

Clinton, G. P., and Britton, W. E.

- 1910 Black rot, *Sphaeropsis Malorum*. *In* Tests of summer sprays on apples and peaches in 1910. Connecticut (New Haven) Agr. Exp. Sta. Ann. rept. 33-34:590, pl. 21, b.

Authors report occurrence of black rot (due to *Sphaeropsis Malorum*) on summer and stored winter varieties. State that the use of insecticides in keeping out codling moth lessens the rot starting from this cause.

Cook, M. T.

- 1913 Report of the Plant Pathologist. New Jersey Agr. Exp. Sta. Ann. rept. 33:509-527.

Black rot of apple and quince, caused by *Sphaeropsis Malorum*, among the diseases listed (p. 512) as most important and most common in the nurseries.

- 1914 a Black rot of the apple and quince. *In* Some diseases of nursery stock. New Jersey Agr. Exp. Sta. Circ. 35:13-14, fig. 9.

Twig and leaf-spot forms of the disease very common in nurseries. It is advised that diseased trees should never be set.

- 1914 b Black rot (*Sphaeropsis Malorum* Pk.). *In* Most common diseases of the year. New Jersey Agr. Exp. Sta. Ann. rept. 34:799, 809.

Black rot of apples most severe on Red Astrachan, Star, Lawver, Smokehouse. Black rot of quince reported as being very abundant and very severe.

Cooke, M. C.

- 1892 *Sphaeropsis pomorum* (Schwz.). *In* Sphaeriaceae imperfectae cognitae. Grevillea 20:86.

Suggests that *Sphaeropsis pomorum* (Schwz.) [= *Sphaeria pomorum* Schwz.] is probably the same as *Sphaeropsis Malorum* Peck, of which *Phoma Malorum* Berk., erected by Saccardo, is possibly a younger condition.

Cooper, J. R.

- 1913 The control of canker in the orchard. Nebraska hort. 3:2:1-2.

Black rot canker is ranked third in importance among cankers in Nebraska. The discussion of control measures is directed at the Illinois blister canker.

Corbett, L. C.

- 1900 Brown spot, frog eye. *In* Fruit diseases and how to treat them. West Virginia Agr. Exp. Sta. Bul. 66:202-204, fig. 2.

Author considers frog-eye, or brown spot (said to be due to *Phyllosticta pirina*), more injurious than either blight or scab.

Crabill, C. H.

- 1915 The frog-eye leaf spot of apples. Virginia Agr. Exp. Sta. Bul. 209:3-16, fig. 1-5.

Author states that frog-eye leaf spot is the most prevalent of apple foliage diseases in Virginia. The annual losses from the disease are said to be heavy in that State, but systematic spraying has controlled the disease in a satisfactory and effective manner. Symptoms are described. Etiological studies are tabulated, and from his experiments the author concludes that frog-eye spots are initiated by *Sphaeropsis Malorum*. All other fungi with which he deals are classed as facultative parasites, following *S. Malorum*, or as pure saprophytes.

Cummings, M. B.

- 1909 Apple orchard survey of Niagara County. Cornell Univ. Agr. Exp. Sta. Bul. 262:277-320, fig. 26-40.

Gives notes (p. 304, table 12) on economic importance of canker.

Dandeno, J. B.

- 1906 A stimulus to the production of cellulose and starch. Michigan Acad. Sci. Rept. 8:40-44.

Claims that the fungus *Sphaeropsis Malorum* stimulates the cells of ripe apple fruit to form starch and to thicken the cellulose walls. Suggests that starch is built up first and then dissolved and built into cellulose, the process going on until the fruit is mummified and dry, whereupon it is in a state of preservation.

Delacroix, G.

- 1903 a Sur un chancre du pommier produit par le *Sphaeropsis Malorum* Peck. Soc. Myc. France. Bul. 19:132-140. Illustrated.

Gives an account of the disease which, it is believed, appeared in France at least as early as 1901. Discusses the morphology of the parasite and the relationship of the mycelium to the tissues of limbs, mentions inoculation experiments, and suggests control measures.

- 1903 b Sur l'identité réelle *Sphaeropsis Malorum* Peck. Soc. Myc. France. Bul. 19:350-352.

Reports the examination of the following type material: *Sphaeropsis Malorum* Peck, *S. Malorum* Berk., *Diplodia maura* Cooke & Ellis, *D. pseudodiplodia* Fckl., and *Botryodiplodia Mali* P. Brunaud. Concludes that *S. Malorum*, *D. maura*, and *B. Mali* are all different, and that *S. Malorum* in France, *S. Malorum* Peck, and *D. pseudodiplodia* Fckl. are identical. States that since *D. pseudodiplodia* was described before *S. Malorum*, the latter name should disappear, and the new combination *S. pseudodiplodia* (Fckl.) G. Del. is proposed.

Dickens, A., and Headlee, T. J.

- 1911 Spraying the apple orchard. Kansas Agr. Exp. Sta. Bul. 174:251-292, fig. 1-19.

Give an account of experimental work in the control of black rot by spraying. Bordeaux mixture and lime-sulfur were used on several varieties.

Douglass, B. W.

- 1910 Black rot. In Plant diseases. Indiana State Entomologist. Rept. 2 (1908-1909):135.

The disease is briefly described.

Duggar, B. M.

- 1909 Black rot and canker of pomaceous fruits. In Fungous diseases of plants, p. 303, 350-354, fig. 169-172.

A discussion of habitat relations, etiology, and control of the fungus.

Edgerton, C. W.

- 1908 Two little-known Myxosporiums. *Ann. myc.* 6:48-53, fig. 1-2.
Points out similarity and difference between the cankers caused by *Sphaeropsis Malorum* and a new species of Myxosporium, called *M. corticolum*. The synonymy of *S. Malorum* is given.

Ellis, J. B.

- 1880 On the variability of *Sphaeria Quercuum* Schw. Philadelphia Acad. Nat. Sci. Proc. 1879:66-70.
Author would include several enumerated species of *Sphaeria*, *Botryosphaeria*, *Dothidea*, and *Melogramma* under one species, and the name *Melogramma fuliginosa* is accepted. Ascigerous forms accompanied by stylospore forms of the *Diplodia* or *Sphaeropsis* type.

Ellis, J. B., and Everhart, B. M.

- 1892 The North American Pyrenomycetes, p. 1-793, pl. 1-41.

Eustace, H. J.

- 1908 Investigations on some fruit diseases. New York (Geneva) Agr. Exp. Sta. Bul. 297:29-48, pl. 1-7.
Shows by experiment that the fungus (*Sphaeropsis Malorum*) is not destroyed but its growth is retarded in storage at temperatures ranging from 29° to 32° F. Gives results of sulfur fumigation in storage.

Evans, I. B. P.

- 1910 The New York apple tree canker or black rot fungus in South Africa. Transvaal agr. journ. 7:62-64, pl. 7.
Calls attention of South African growers to the presence of "another imported fungus, and one which it will not be well to neglect."

Faurot, F. W.

- 1903 Black rot. In Report of fungous diseases occurring on cultivated fruits during the season of 1902. Missouri State Fruit Exp. Sta. Bul. 6:6-7.
The name *blossom rot* is employed for calyx-end infections on apples. Symptoms are described.
- 1912 Black rot. In Common orchard troubles, spray mixtures, and spray calendar. Missouri State Fruit Exp. Sta. Bul. 23:14-15, fig. 8-9.
States that black rot, also called blossom-end rot, occurs largely on fruits of which the skin has been broken, and that owing to the habits of the fungus it is not controlled by spraying.

Floyd, Bayard F.

- 1905 Apple canker. Black rot. In Some common fungous diseases and their treatment. Missouri State Hort. Soc. Ann. rept. 48:432.
Notes that windfall apples are very susceptible.

Freeman, E. M.

- 1905 Black rot of apple (*Sphaeropsis Malorum* Peck). In Minnesota plant diseases, p. 363-364, fig. 194.
Gives a short general account of black rot, leaf spot, and canker.

Fückel, L.

1869 *Symbolae mycologicae*, p. 1-459, pl. 1-6.

Descriptions of *Diplodia pseudodiplodia* Fekl. (p. 393) and *Diplodia Malorum* Fekl. (p. 395).

Galloway, B. T.

1892 Report on the experiments made in 1891 in the treatment of plant diseases. U. S. Agr. Dept., Veg. Path. Div. Bul. 3:1-76. Illustrated.

Gives (p. 39) an account of petal and young fruit infection induced by *Sphaeropsis Malorum*.

Garman, H.

1895 Spraying experiments in 1895. Kentucky Agr. Exp. Sta. Bul. 59:111-129. Illustrated.

Sphaeropsis Malorum said (p. 127) to be the cause of most of the fruit rot in the State.

1908 Brown rot of apples. In 1. Spraying apple trees. 2. Apple orchard pests in Kentucky. Kentucky Agr. Exp. Sta. Bul. 133:8, 65-66.

The disease on apple fruit (due to *Sphaeropsis Malorum*) is called brown rot, and spraying experiments for the control of the disease are reported.

Giddings, N. J.

1908 Apple canker. In The occurrence of plant diseases in 1907. Vermont Agr. Exp. Sta. Ann. rept. 20:331.

Apple canker, caused by *Sphaeropsis Malorum*, said to be rather prevalent in some orchards. The statement is made that the disease is easily controlled by pruning and spraying, and is thus kept down in most well-tended orchards.

Green, W. J., Selby, A. D., and Gossard, H. A.

1915 Spraying program for orchards with combinations recommended. Ohio Agr. Exp. Sta. Circ. 149:53-60.

Suggest (p. 54-55) a combination of insecticide and fungicide for control of codling moth, apple scab, and black rot.

Griffon, E., and Maublanc, A.

1910 Sur des espèces de *Sphaeropsis* et de *Diplodia* parasites du poirier et du pommier. Soc. Myc. France. Bul. 26:307-316. Illustrated.

Discuss symptoms, and several species of fungi on apple and pear. The conclusion is reached that these trees may be attacked by *Sphaeropsis* and *Diplodia*, which act as wound parasites. The species involved are regarded as distinct and are briefly described; these are *Sphaeropsis Malorum* Peck, *Sphaeropsis pseudodiplodia* (Fekl.) Del., and an undetermined *Diplodia*.

Güssow, H. T.

1911 Black rot (*Sphaeropsis Malorum* Peck.). In Report of the Dominion Botanist. Experimental Farms (Canada). Rept. 1911:246-247.

Discusses symptoms and control.

Halsted, B. D.

- 1892 The black rot of the quince. *In* Some fungous diseases of the quince fruit. New Jersey Agr. Coll. Exp. Sta. Bul. 91:8-10, fig. 5-6.

Concludes from observation and experiment that the species of *Sphaeropsis* on quince, apple, and pear are the same. States that the fungus causes one of the most destructive decays of the quince, and that the spores pass through the air or are carried by insects.

- 1894 Decays of mature apples. *In* Report of the Botanist. New Jersey Agr. Exp. Sta. Ann. rept. 14:367-377, fig. 35-41.

Symptoms of black rot well described (p. 374-375). Author makes the point that the fungus probably gains access through remnants of the flower at the free end.

Harrison, Charles

- 1823 A treatise on the culture and management of fruit trees, p. 1-356. Illustrated.

Attributes (p. 341-343) canker to such causes as injudicious pruning, bruising, nailing, bad subsoil. Surgical methods recommended.

Hartig, R.

- 1894 Text-book of the diseases of trees, p. 1-331. (Translated by Somerville and Ward.)

Hartley, C. P.

- 1908 a Some apple leaf-spot fungi. *Science* n. s. 27:212.

Reports the finding of eighteen different species of fungi on apple leaf spots in West Virginia, *Sphaeropsis Malorum* being among the common ones.

- 1908 b Some apple leaf-spot fungi. *Science* n. s. 28:157-159.

Gives brief historical review of the question of the etiology of apple leaf spot. A list of several species of fungi found on spotted leaves is given, and inoculation experiments with certain of these are reported. Results indicate that *Coniothyrium pirina* is a wound parasite, while *Coryneum foliicolum* appeared to be even less parasitic.

- 1913 Twig canker on black birch. *Phytopath.* 3:248-249.

Reports the isolation of a *Sphaeropsis*, closely resembling *S. Malorum* but with somewhat smaller spores, from swollen cankered black birch twigs (*Betula lenta* L.). Inoculation experiments show that the organism is parasitic *only* under certain conditions, nor is it regarded as the cause of the swollen cankers.

Heald, F. D.

- 1906 The black-rot of apples due to *Sclerotinia fructigena*. Nebraska Agr. Exp. Sta. Ann. rept. 19:82-91. Illustrated. (See also p. 22, 61.)

Points out that the term *black rot* is a confused one, having been used for diseases caused by both *Monilia* and *Sphaeropsis*. The two diseases are compared and contrasted as to symptoms.

Hedges, Florence, and Tenny, L. S.

- 1912 A knot of citrus trees caused by *Sphaeropsis tumefaciens*. U. S. Plant Indus. Bur. Bul. 247:1-74. Illustrated.

Hesler, L. R.

- 1912 The New York apple tree canker. Indiana Acad. Sci. Proc. 1911:325-339, fig. 1-7.

Gives data concerning the geographical distribution, importance, symptoms, etiology, and control of the disease. The synonymy of the fungus is reviewed.

- 1913 *Physalospora Cydoniae*. *Phytopath.* 3:290-295. Illustrated.
Proves experimentally the genetic connection between *Physalospora Cydoniae* and *Sphaeropsis Malorum*.

- 1914 Biological strains of *Sphaeropsis Malorum*. *Phytopath.* 4:45.
Results of cross-inoculation work with the fungus from several host plants indicate that there is one large morphological species embracing many biological races.

Hewitt, J. L., and Hayhurst, P.

- 1911 Diseases of apple trees and fruit caused by fungi and insects.
Arkansas Agr. Exp. Sta. Bul. 109:409-445.
Note the occurrence of black rot and leaf spot in Arkansas (p. 438, 440-441).

Howitt, I. E.

- 1913 Fungus diseases. Ontario Agr. Coll. and Exp. Farm. Ann. rept. 38:29-30.
Notes the occurrence of black rot canker along with other plant diseases.

Ingram, Della

- 1912 Preliminary notes on a twig blight of *Quercus prinus*. *Phytopath.* 2:96-97.
Mentions an apparently serious disease of the chestnut oak which occurs in Connecticut, Virginia, Maryland, and Pennsylvania. The organism associated with the disease is said to agree with *Dothiorella quercina* (C. & Ell.). (Cf. Rankin, W. H., 1914, p. 141.)

Jehle, R. A.

- 1913 The brown rot canker of the peach. *Phytopath.* 3:105-110, pl. 10, fig. 1-5.
Reports successful use of coal tar on wounds of peaches.

Jones, L. R., and Giddings, N. J.

- 1907 Apple canker. In The occurrence of plant diseases in Vermont in 1906. Vermont Agr. Exp. Sta. Ann. rept. 19:231-232.
The fungus *Sphaeropsis Malorum* said to continue its destructive invasion and to be the cause of every case of apple canker examined.

Kern, F. D.

- 1906 Indiana plant diseases in 1905. Purdue Univ. Agr. Exp. Sta. Bul. 111:121-134.
Black rot of the apple, pear, and quince reported (p. 125) from the southern part of the State only.
- 1907 Indiana plant diseases in 1906. Purdue Univ. Agr. Exp. Sta. Bul. 119:425-436.
Mentions (p. 428) black rot and canker of the apple, and black rot of quince, present to some extent in the southern part of the State.

Kinney, L. F.

- 1895 a Some special orchard treatment of the apple, pear, and quince. Rhode Island Agr. Exp. Sta. Bul. 31:1-17, fig. 1-9.
Reports (p. 10) failure to control black rot of quince by spraying.
- 1895 b The leaf spot of the apple and pear. In Horticultural Division. Rhode Island Agr. Exp. Sta. Ann. rept. 7:188-189, fig. 7-8.
Points out resemblance of injury by apple leaf miner (*Tischeria malifoliella* Clemens) to apple leaf spot. Spots on the leaves, and spores of *Phyllosticta pirina*, which is regarded as the cause, are figured.

- 1895 c The brown rot. *In* Horticultural Division. Rhode Island Agr. Exp. Sta. Ann. rept. 7:192-193, fig. 12.

Symptoms are given. The disease on the fruit (which author calls brown rot) and spores of the fungus are figured.

Kirchner, Oskar

- 1906 Die Krankheiten und Beschädigungen unserer landwirtschaftlichen Kulturpflanzen, p. 1-647.

States (p. 440) that the canker disease of apple trees, caused by *Diplodia pseudodiplodia* Thum., occurs in North America, France, and perhaps Germany.

Lamson, H. H.

- 1897 Department of Bacteriology. *In* Ninth annual report. New Hampshire Coll. Agr. Exp. Sta. Bul. 48:146-147.

Bordeaux mixture said to have had little effect in controlling leaf spot due to *Phyllosticta pirina*; hence work was directed toward its control.

- 1899 Apple diseases. *In* Notes on apple and potato diseases. New Hampshire Coll. Agr. Exp. Sta. Bul. 65:106-107, fig. 38-39.

Notes the serious nature of leaf spot, which is said to be caused partly at least by *Phyllosticta pirina*.

- 1901 Apple tree canker. *In* Thirteenth annual report. New Hampshire Coll. Agr. Exp. Sta. Bul. 87:130.

Reports the presence of a canker which is believed to be caused by a fungus.

- 1902 The cold storage of apples.—Part II. Influence of cold storage on the decay of apples. Effect of wrapping apples in paper. New Hampshire Coll. Agr. Exp. Sta. Bul. 93:75-81, fig. 1.

Sphaeropsis Malorum listed (p. 75) as one of three fungi which cause most of the rotting. Author concludes (p. 81) that a temperature of 34° F. is more effective than 40° to 45° F., and that wrapping the fruit is of decided advantage in extending the keeping period beyond the first of June. Clean newspaper said (p. 81) to be just as effective as more expensive paper.

- 1903 Leaf spot. *In* Fungous diseases and spraying. New Hampshire Coll. Agr. Exp. Sta. Bul. 101:61-62. Illustrated.

Bordeaux mixture said to have little effect in controlling leaf spot of apple.

Lewis, C. E.

- 1909 Apple diseases caused by *Coryneum foliicolum* and *Phoma Mali*. Maine Agr. Exp. Sta. Bul. 170:183-200, fig. 17-42.

Reports successful infection experiments with *Sphaeropsis Malorum* Peck on injured bark and on uninjured apple leaves.

- 1912 Inoculation experiments with fungi associated with apple leaf spot and canker. *Phytopath.* 2:49-62.

An account of experiments directed toward the determination of the parasitism of such fungi as *Sphaeropsis Malorum*, *Phyllosticta limitata* Peck, *Coniothyrium pirina* (Sacc.) Sheldon, and *Coryneum foliicolum* Peck. Author concludes that a part of the leaf spot in Maine is due to *Sphaeropsis Malorum*, but that a similar spotting is due to bordeaux mixture; that *Sphaeropsis Malorum* is the only fungus isolated from apple leaves in the State which causes spots when inoculations are made from pure cultures; and that, of the several fungi studied, this fungus does the greatest damage to branches and to twigs.

Lewis, I. M.

- 1908 Apple leaf spot. New Hampshire Agr. Exp. Sta. Ann. rept. 19-20:365-369, pl. 8-9.

Gives a historical review of the causal nature of the disease, and presents inoculation and control data.

Lochhead, William

- 1905 Black rot canker. Ontario Agr. Coll. and Exp. Farm. Ann. rept. 30:49, fig. 4-5.

Defines the term *canker* and outlines control measures.

- 1909 Apple diseases. In Fungous diseases in Quebec in 1908. Quebec Soc. Prot. Plants from Ins. and Fung. Dis. Ann. rept. 1:31.

The prevalence of the canker form of this disease is noted.

Longyear, B. O.

- 1904 Fungous diseases of fruits in Michigan. Michigan State Agr. Coll. Exp. Sta. Spec. bul. 25:1-68, fig. 1-42.

Records the black rot disease of apple (p. 10-13), pear (p. 16), and quince (p. 20).

Lunge, George

- 1909 Coal tar and ammonia, Part I, chap. 1, p. 1-15.

Notes differences in tars, both physical and chemical, depending on the origin. Tar obtained from the same material also differs very much in composition, according to the temperature of the dry distillation, and even according to the shape of the retorts.

McAlpine, D.

- 1902 Fungus diseases of stone-fruit trees in Australia and their treatment, p. 1-165. Illustrated.

Lists (p. 133, 134) *Diplodia Malorum* on peach and plum twigs.

M'Cormack, Edna F.

- 1910 Black rot of the apple. In Fungous diseases of the apple. Indiana State Entomologist. Rept. 3:142-144. Illustrated.

Symptoms discussed.

McCready, S. B.

- 1910 Black rot canker (*Sphaeropsis Malorum* Peck). Ontario Agr. Coll. and Exp. Farm. Ann. rept. 35:41-42.

Brief reference to hosts, distribution, etiology, and control.

- 1911 Black rot of apple. Ontario Agr. Coll. and Exp. Farm. Ann. rept. 36:37.

Reports use of lead paint and gas tar as wound dressings; the latter found to give better protection.

Mangin, L.

- 1901 Sur une nouvelle maladie des pommiers causée par le "*Diplodia pseudo-diplodia*." Journ. agr. prat. n. s. 2:138-139.

Reports occurrence of the disease on apple branches in France, and gives suggestions for control.

Morse, W. J.

- 1909 Notes on plant diseases, 1908. Maine Agr. Exp. Sta. Bul. 164:1-28. Illustrated.

States (p. 3-4) that *Sphaeropsis Malorum* from leaf spot produced decay of fruit as a result of artificial inoculation. States (p. 10) that self-boiled lime-sulfur seemed effective in controlling leaf spot.

Morse, W. J., and Lewis, C. E.

- 1910 Maine apple diseases. Maine Agr. Exp. Sta. Bul. 185:335-392. Illustrated.

Notes on the etiology of leaf spot and canker. Canker fungus in Maine orchards follows frost injury.

Munson, W. M.

- 1909 Apple enemies, and how to fight them. West Virginia Univ. Agr. Exp. Sta. Bul. 121:353-366.

Control measures for leaf spot and canker given (p. 360-362).

Norton, J. B. S., and Symons, T. B.

- 1907 Black-rot (*Sphaeropsis Malorum*). In Control of insect pests and diseases of Maryland crops. Maryland Agr. Exp. Sta. Bul. 115:178.

Give brief recommendations for the control of black rot, leaf spot, and canker.

O'Gara, P. J.

- 1902 Notes on canker and black-rot. Science n. s. 16:434-435.

Notes a case of girdling of branches of sumac (*Rhus glabra* L.) by *Sphaeropsis rhoina* (Schw.) Starb., which fungus, after careful cultural and inoculation experiments, is regarded as probably identical with *Sphaeropsis Malorum*.

Orton, C. R.

- 1914 Black rot. In Some orchard diseases and their treatment. Pennsylvania State Hort. Assoc. Proc. 55:43-56. Illustrated.

Author states that *Sphaeropsis Malorum* rarely if ever produces cankers on its own initiative. He notes its wide occurrence on various plants, and says that a perfect stage has recently been found on apple, quince, oak, grape, witch-hazel, and other hosts.

Orton, W. A.

- 1902-1907 Plant diseases in the United States in 1901-1907. U. S. Agr. Dept. Yearbook 1901:669; 1902:715; 1903:550; 1904:582-583; 1905:603-604; 1906:499-500; 1907:577-579.

Gives notes on the occurrence and destructiveness of black rot, leaf spot, and canker of apple, pear, and quince.

Paddock, Wendell

- 1898 a An apple canker. Science n. s. 8:595-596.

Reports preliminary experiments in canker investigation. Cultures of fungi from cankers showed *Schizophyllum commune*, and a dark-spored fungus which is said to resemble *Sphaeropsis Malorum* Peck.

- 1898 b Additional notes on an apple canker. Science n. s. 8:836-837.

Suggests that *Sphaeropsis Malorum* Peck is parasitic on the wood of pear and quince as well as on that of apple. Cross-inoculations of the fruits of these three plants gave positive results.

- 1899 a An apple canker. Western New York Hort. Soc. Proc. 44:58-63. Illustrated.

(See 1899 b, of which this is a popular presentation.)

- 1899 b The New York apple-tree canker. New York (Geneva) Agr. Exp. Sta. Bul. 163:177-206, pl. 1-6.

Contains an account of host relationships, names of the disease, symptoms, etiology, and control. Presents conclusive data proving that *Sphaeropsis Malorum* is the cause of canker on apple; considerable data indicate that this species of *Sphaeropsis* also occurs on many other plants.

- 1900 The New York apple-tree canker (Second report). New York (Geneva) Agr. Exp. Sta. Bul. 185:203-213, pl. 1-4.

States that *Sphaeropsis Malorum* occurs on apple, pear, and quince fruits, and on apple, pear, and hawthorn trees; and that it probably occurs on several other plants, but experiments are not regarded as warranting this as a definite conclusion. Notes that apple leaves are occasionally attacked by a *Sphaeropsis*.

Parkinson, John

- 1629 Paradisi in sole paradisius terrestris, p. 1-612. Illustrated.

Briefly outlines (p. 550) the nature and control of canker. Of historical importance.

Parrot, P. J., and Fulton, B. B.

- 1913 Notes on tree crickets. Journ. econ. ent. 6:177-180. Illustrated.

Note that the penetration of apple bark tissues by the ovipositor of the tree cricket is apparently attended by an infection of some unknown fungus or bacterium, which results in the formation of a canker indistinguishable in its appearance and effects from the New York apple tree canker or the fire blight canker.

- 1914 Tree crickets injurious to orchard and garden fruits. New York (Geneva) Agr. Exp. Sta. Bul. 388:415-461. Illustrated.

Authors note (p. 442) that injuries by tree crickets are followed by some infectious agent, and that these lesions, in their external appearances and their effects, resemble superficially certain stages of the New York apple tree canker caused by *Sphaeropsis Malorum*.

Peck, C. H.

- 1879 Report of the Botanist. New York State Mus. Nat. Hist. Ann. rept. 31:19-60.

Reports (p. 20-21) the discovery of *Sphaeropsis Malorum* on apple fruits in Schoharie County.

- 1881 Report of the Botanist. New York State Mus. Nat. Hist. Ann. rept. 34:24-58, pl. 1-4.

Describes (p. 36) symptoms of black rot, and points out the fact that the distinction between *Sphaeropsis* and *Diplodia* sometimes fails, since both one- and two-celled spores are found in the same spore case.

Pollock, J. B., and Kauffman, C. H.

- 1905 Michigan fungi. Michigan Acad. Sci. Rept. 7:57-67.

List *Sphaeropsis Mali* (West.) Sacc. and *S. Malorum* Peck.

Potebnia, A.

- 1907 Mycologische Studien. Ann. myc. 5:1-28, pl. 1-3, fig. 1-43.

Discusses mycelial development, including spore germination and protoplasmic streaming.

- 1910 Beiträge zur Micromycetenflora Mittel-Ruslands. Ann. myc. 8:42-93, fig. 1-38.

States that the pycnidia of *S. pseudodiplodia* (Fckl.) Del. arise meristogenetically.

- 1912 Pilzliche Symbionten. 2. *Sphaeropsis* und *Helicomyces*, p. 28. Illustrated. (Separate sent by Potebnia to the writer.)

Price, H. L.

- 1909 Black rot. In Fighting the insect pests and diseases of orchard, field, and garden crops. Virginia Agr. Exp. Sta. Circ. 7:10-11, fig. 2.

Recommendations for the control of black rot, leaf spot, and canker.

Quaintance, A. L., and Scott, W. M.

- 1912 Apple leaf-spot. In The more important insect and fungous enemies of the fruit and foliage of the apple. U. S. Agr. Dept. Farmers' bul. 492:35-36, fig. 20.

Discuss the importance, symptoms, etiology, and control of apple leaf spot caused by *Sphaeropsis Malorum*.

Rankin, W. H.

- 1914 *Sphaeropsis* canker of *Quercus prinus*. Phytopath. 4:44-45.

Reports *Sphaeropsis Malorum* Berk. as causing twig and limb cankers on chestnut oak (*Quercus prinus* L.), the account being based on observation and inoculation experiments. Regards the disease as the one described by Miss Della Ingram in Phytopathology 2:96 (p. 136).

Reddick, Donald

- 1912 Frost injury. New York State Fruit Growers' Assoc. Proc. 11:34-41, fig. 1-2.

Sphaeropsis Malorum said to be usually found following frost injury.

Reed, H. S.

- 1908 Fall blossoming of the apple induced by the black rot. Plant world 11:256-257.

Notes a case in which *Sphaeropsis Malorum* inhibited the normal activities of an apple tree, allowing the tissues to carry on the growth which would normally have been deferred for several months, and resulting in the unfolding of normal blossoms on October 5.

Reed, H. S., and Cooley, J. S.

- 1911 Black rot (*Sphaeropsis Malorum*). In Plant diseases in Virginia in the years 1909 and 1910. Virginia (Polytech. Inst.) Agr. Exp. Sta. Ann. rept. 1909-1910:102-103, fig. 21.

Record black rot, leaf spot, and canker. Report pycnosporos discharging from pycnidia on leaves at Blacksburg on June 25, 1910.

Reed, H. S., Cooley, J. S., and Rogers, J. T.

- 1912 Foliage diseases of the apple. Virginia (Polytech. Inst.) Agr. Exp. Sta. Bul. 195:1-24, fig. 1-13.

Give points concerning the varietal susceptibility of apples; the distribution, importance, and symptoms of the disease; and the life history of the fungus.

Reed, H. S., and Crabill, C. H.

- 1913 Black rot (*Sphaeropsis Malorum*). In Plant diseases in Virginia in the years 1911 and 1912. Virginia (Polytech. Inst.) Agr. Exp. Sta. Ann. rept. 1911-1912:36, fig. 3.

Note that *Sphaeropsis Malorum* occurs on twigs previously killed by the fire blight organism. Figure a multilocular sterile (?) pycnidium.

Reed, H. S., and Stahl, H. S.

- 1911 The erepsins of *Glomerella rufomaculans* and *Sphaeropsis Malorum*. Journ. biol. chem. 10:109-112.

Authors find evidence of erepsin produced in pure cultures.

Roberts, J. W.

- 1913 The "rough-bark" disease of the Yellow Newtown apple. U. S. Plant Indus. Bur. Bul. 280:1-15, pl. 1-3.

Reports (p. 9, 15) *Phomopsis Mali*, a new species, associated with *Sphaeropsis Malorum* on leaf spots.

- 1914 Experiments with apple leaf-spot fungi. Journ. agr. research 2: 57-66, pl. 7, fig. 1-3.

Reports the isolation of several species, including *Sphaeropsis Malorum*, from apple leaf spots. A new species, *Alternaria Mali*, is in the list and is technically described. From experiments conducted it is concluded that this species may be classed as a rather strong facultative parasite.

Rose, D. H.

- 1914 Ring rot. Also, Black rot (*Sphaeropsis Malorum*). In Biennial report. Missouri State Fruit Exp. Sta. Bul. 24 (Bienn. rept. 1913-1914): 20, 23-24, pl. 5, fig. 1-2.

Ring rot, or blossom-end rot, of the apple fruit thought to be due to frost injury at blossoming time, followed by *Sphaeropsis Malorum* Peck. Author gives notes on the destructiveness of black rot.

Ruggles, A. G., and Stakman, E. C.

- 1911 Black rot In Orchard and garden spraying. Minnesota Univ. Agr. Exp. Sta. Bul. 121: 15.
Symptoms of black rot given.

Saccardo, P. A.

- 1884 a *Phoma Malorum* (Berk.) Sacc. Syll. Fung. 3: 152-153.

A technical Latin description is given. Author lists *Sphaeropsis Malorum* Berk. in synonymy.

- 1884 b *Sphaeropsis Malorum* Peck. Syll. Fung. 3: 294.

Describes the fungus which Peck (1881) reports and regards as new, thus giving rise to the name *Sphaeropsis Malorum* Peck.

Salmon, E. S.

- 1907 Apple leaf-spots. Gard. chron. ser. 3: 42: 305-306, fig. 120-124.

A brief discussion of varietal susceptibility and etiology of leaf spots caused by a species of *Phyllosticta* and one of *Sphaeropsis*. The author is in doubt as to whether the latter species is *S. Malorum*.

Scott, W. M.

- 1906 The control of apple bitter-rot. U. S. Plant Indus. Bur. Bul. 93: 1-36, pl. 1-8.

Gives (p. 27-33) results of experiments for the control of leaf spot in connection with apple scab, sooty blotch, and bitter rot.

- 1908 Apple leaf-spot. In Self-boiled lime-sulphur mixture as a promising fungicide. U. S. Plant Indus. Bur. Circ. 1: 12.

States that it appears that leaf spot may be prevented by this fungicide, but no data are cited.

- 1912 Apple leaf-spot, or frog-eye. In Spraying to control the important insects and fungous diseases affecting the fruit and foliage of the apple. Thomsen Chemical Co. (Baltimore, Md.). Circ. 4: 14-15, pl. 2, fig. 1.

Scott, W. M., and Quaintance, A. L.

- 1907 Leaf-spot diseases. In Spraying for apple diseases and the codling moth in the Ozarks. U. S. Agr. Dept. Farmers' bul. 283: 18-20, fig. 3.

Authors give recommendations for the control of leaf spot, which, as they state, may be due to *Sphaeropsis Malorum*.

Scott, W. M., and Rorer, J. B.

- 1908 Apple leaf-spot caused by *Sphaeropsis Malorum*. U. S. Plant Indus. Bur. Bul. 121:45-54, pl. 3-4.

Authors discuss the common names of the leaf spot, its history, geographical occurrence, importance, symptoms, etiology, and control. Proof of the pathogenicity of *Sphaeropsis Malorum* on apple leaves is given, together with a study of the rôle of associated fungi on leaf spots.

- 1909 Apple blotch, a serious disease of Southern orchards. U. S. Plant Indus. Bur. Bul. 144:1-28, pl. 1-6.

Authors suggest (p. 11) that *Sphaeropsis Malorum* is a factor in the killing of apple buds. Further investigation is deemed desirable.

Scribner, F. L.

- 1890 Black-rot of the apple. Fungus diseases of the grape and other plants and their treatment, p. 81-83, fig. 1606.

Descriptions of the disease and of the fungus, called *Macrophoma Malorum*, are given.

Seaver, F. J.

- 1908 Color variation in some of the fungi. Bul. Torrey Bot. Club 35:307-314.

Points out that color characters are misleading and misused in the Hypocreales.

Selby, A. D.

- 1900 A condensed handbook of the diseases of cultivated plants in Ohio. Ohio Agr. Exp. Sta. Bul. 121:1-69, fig. 1-54.

Notes (p. 14) the disease on the leaves and fruit of apple and quince.

- 1910 Black-rot. In A brief handbook of the diseases of cultivated plants in Ohio. Ohio Agr. Exp. Sta. Bul. 214:368-369, 436, fig. 1-105.

Notes the importance of the disease in Ohio.

- 1913 Disease susceptibility of apple varieties in Ohio. Ohio Agr. Exp. Sta. Circ. 133:53-56.

Indicates degree of susceptibility of apple varieties to black rot and canker.

Shear, C. L.

- 1910 Life history of *Melanops Quercuum* (Schw.) Rehm forma *Vitis* Sacc. Science n. s. 31:748.

Pure cultures of ascospores of *Melanops Quercuum* (Schw.) Rehm forma *Vitis* Sacc. [= *Bolryosphaeria Berengeriana* de Not. = *B. fuliginosa* (M. & N.) E. & E.] said to produce a pycnidial form which agrees with *Sphaeropsis Malorum* Berk. and *Diplodia pseudodiplodia* Fekl.

- 1913 Some observations on phytopathological problems in Europe and America. Phytopath. 3:77-87.

Sphaeropsis Malorum reported (p. 81-82) as doing no noticeable injury in orchards from Italy to England.

- 1914 Life history of *Sphaeropsis Malorum* Berk. Phytopath. 4:48-49.

Concludes from cultural studies the ascosporic form of *Sphaeropsis Malorum* Berk. is *Melanops Quercuum* f. *Vitis*.

Shear, C. L., and Wood, Anna K.

- 1913 Studies of fungous parasites belonging to the genus *Glomerella*. U. S. Plant Indus. Bur. Bul. 252:1-110. Illustrated.

Discuss host relationships, variability, and parasitism of *Glomerella*.

Sheldon, J. L.

- 1905 A report on plant diseases of the State. West Virginia Univ. Agr. Exp. Sta. Bul. 96:69-99. Illustrated.
Black rot (p. 74), leaf spot (p. 74-75), and canker (p. 74) reported.
- 1907 The taxonomy of a leaf-spot fungus of the apple and other fruit-trees. *Torreyia* 7: 142-143.
The name of the leaf spot, or frog-eye, organism is changed from *Phyllosticta pirina* Sacc. to *Coniothyrium pirina* (Sacc.) Sheldon.
- 1908 Another leaf-spot fungus of the apple. *Torreyia* 8: 139-141.
Illosporium malifoliorum n. sp. is said to be concerned with the leaf spot, in a secondary manner. This fungus is described.

Smith, R. I., and Stevens, F. L.

- 1910 Leaf spot. Also, Black rot. In Insects and fungous diseases of apple and pear. North Carolina Agr. Exp. Sta. Bul. 206: 94, 95, 102-103, fig. 23.
Call the disease *Sphaeropsese*, and state that perhaps one, but probably several, species are responsible for leaf spot.

Stene, A. E.

- 1910 Some suggestions for Rhode Island apple growers. Rhode Island State Agr. Bd. Ann. rept. 25:93-181. Illustrated.
Leaf spots and canker said to be general in the State (p. 152-153).

Stevens, F. L., and Hall, J. G.

- 1907 Sphaeropsis on apple twigs. In Some apple diseases. North Carolina Agr. Exp. Sta. Bul. 196: 52-53.
- 1909 a Notes on plant diseases occurring in North Carolina. North Carolina Agr. Exp. Sta. Ann. rept. 31: 66-82, fig. 1-10.
Black rot and canker reported (p. 66). Sphaeropsis and an ascomycetous fungus found; name of latter not given. Sphaeropsis reported (p. 75) as a canker-producing fungus on pear.
- 1909 b Variation of fungi due to environment. Bot. gaz. 48: 1-30, fig. 1-37. See also North Carolina Agr. Exp. Sta. Ann. rept. 32 (1908-1909): 47-71, fig. 1-37.
Authors discuss observations on the influence of environment on the characters of certain fungi.

Stevens, F. L., and Sherman, F.

- 1903 The black rot. Also, The black rot of the quince. In Insect and fungus enemies of the apple, pear, and quince, with methods of treatment. North Carolina Agr. Exp. Sta. Bul. 183: 72, 82, fig. 1-22.
Symptoms and control measures of black rot and canker given.

Stewart, F. C.

- 1896 A new leaf-spot disease of apples. In Report of the Mycologist. New York (Geneva) Agr. Exp. Sta. Ann. rept. 14 (1895): 545-546.
Records *Phyllosticta limitata* n. sp. on apple leaves on Long Island. Technical description given.

- 1904 Apple canker. *In* Fungi and fungous diseases. Western New York Hort. Soc. Proc. 49: 53.

States that spraying for apple canker caused by *Sphaeropsis Malorum* is only a partial preventive; a matter not understood.

- 1909 Apple leaf spot. *In* Recent investigations on plant diseases. Western New York Hort. Soc. Proc. 54: 78-79.

Believes that the leaf spot problem in New York is not completely solved. Points out that spraying often fails to control.

- 1910 Notes on New York plant diseases, I. New York (Geneva) Agr. Exp. Sta. Bul. 328: 303-404, pl. 1-18.

Discusses (p. 312-313) occurrence of leaf spot in New York. Gives (p. 323-324) an account of a peculiar disease of the trunk of Walbridge apples and suggests that *Sphaeropsis Malorum* may have been a factor in producing the same. Suspects (p. 377-379) that the fungus also causes the failure of grafts of the pear.

Stewart, F. C., and Blodgett, F. H.

- 1899 A fruit-disease survey of the Hudson Valley in 1899. New York (Geneva) Agr. Exp. Sta. Bul. 167: 273-308, pl. 1-4.

Notes on the geographical occurrence of the leaf spot and canker in the Hudson Valley (p. 283, 284, 301-302).

Stewart, F. C., and Eustace, H. J.

- 1902 Two unusual troubles of apple foliage. New York (Geneva) Agr. Exp. Sta. Bul. 220: 215-233, pl. 1-5.

Authors conclude that spray material caused spotting of apple foliage; suspect the parasitism of *Phyllosticta*; suggest that drops of rain may act as lenses and concentrate the sun's rays, overheating the tissue beneath.

Stewart, F. C., Rolfs, F. M., and Hall, F. H.

- 1900 A fruit-disease survey of western New York in 1900. New York (Geneva) Agr. Exp. Sta. Bul. 191: 289-331, pl. 1-6.

Note geographical occurrence of the disease in western New York.

Stone, G. E.

- 1914 Lime and sulfur solutions. Massachusetts Agr. Exp. Sta. Circ. 39: 1-4.

Lime and sulfur said to hold leaf spot in check, and believed to have material effect on cankers.

Stone, G. E., and Fernald, H. T.

- 1908 Canker. *In* Fungicides, insecticides, and spraying directions. Massachusetts Agr. Exp. Sta. Bul. 123: 16.

Suggestions for canker control are given.

Stone, G. E., and Monahan, N. F.

- 1907 The lime and sulfur mixture as a fungicide. *In* Report of the Botanist. Massachusetts (Hatch) Agr. Exp. Sta. Ann. rept. 19: 167.

State that observations seem to indicate that spraying with lime and sulfur succeeds to some extent in controlling canker.

Stone, G. E., and Smith, R. E.

- 1903 Apple-leaf spot. *In* Report of the Botanists. Massachusetts (Hatch) Agr. Exp. Sta. Ann. rept. 15: 27, 32-34.

Frost followed by cold wet weather caused apple leaf spot.

Sturgis, W. C.

- 1893 a Black-rot (*Sphaeropsis Malorum* Peck). *In* Common fungous diseases and their treatment. Connecticut (New Haven) Agr. Exp. Sta. Bul. 115:6-7.

Black rot of apple, quince, and pear noted.

- 1893 b Black rot of quinces. *In* Report of the Mycologist. Connecticut (New Haven) Agr. Exp. Sta. Ann. rept. 1892:43-44.
Description of black rot disease of quince fruits.

- 1894 Black rot (*Sphaeropsis Malorum* Peck). *In* Report of the Mycologist. Connecticut (New Haven) Agr. Exp. Sta. Ann. rept. 17:78-79.

Reports inoculation and spore germination data. States that the wind and other agencies carry the fungus spores.

Taft, L. R., and Davis, G. C.

- 1895 Black rot (*Sphaeropsis Malorum* Berk.). *In* The pests of the orchard and garden. Michigan State Agr. Coll. Exp. Sta. Bul. 121:21.

Briefly describe black rot and give suggestions for control.

Taubenhaus, J. J.

- 1912 A further study of some Gloeosporiums and their relation to a sweet pea disease. *Phytopath.* 2:153-160, pl. 16, fig. 1-19.

States (p. 157) in a footnote that black rot was very prevalent in the very dry summer of 1911.

Taylor, W. A.

- 1914 Fruit diseases. *In* Report of the Chief of the Bureau of Plant Industry. U. S. Agr. Dept. Rept. 1913:105-133.

States (p. 107) that a variety of *Melanops Quercuum* has been shown to be the perfect stage of *Sphaeropsis Malorum*.

Thümen, F. von

- 1879 Fungi pomicoli, p. 108. (Cited from Baccarini, 1890.)

Waite, M. B.

- 1898 a An apple canker. Western New York Hort. Soc. Proc. 43:9-11.

Briefly outlines the history and distribution of the disease, and suggests that the cause may be *Schizophyllum commune*. Control measures suggested.

- 1898 b An apple canker. Rural New-Yorker 57:82, fig. 32.

Essentially the same paper as the preceding.

- 1906 Fungicides and their use in preventing diseases of fruits. U. S. Agr. Dept. Farmers' bul. 243:1-32, fig. 1-17.

Brief notes (p. 19) on control of black rot, leaf spot, and canker.

- 1908 Apple leaf blight. *In* Diseases of orchard trees and fruits. Pennsylvania Agr. Dept. Ann. rept. 13:450-452.

Gives treatment for leaf spot.

- 1910 Experiments on the apple with some new and little-known fungicides. U. S. Plant Indus. Bur. Circ. 58:1-19.

Notes on leaf spot.

Walker, Leva B.

- 1908 A new form of *Sphaeropsis* on apples. Nebraska Agr. Exp. Sta. Ann. rept. 21:34-44, fig. 1-10.

Compares typical *Sphaeropsis Malorum* with a new form, the latter having larger spores, pycnidia with long necks, and no ostiole, and being more virulent in producing black rot.

Wallace, Errett

- 1913 Scab disease of apples. Cornell Univ. Agr. Exp. Sta. Bul. 335:541-624. Illustrated.

Warren, G. F., and McCourt, W. E.

- 1905 The apple-tree canker. In An apple orchard survey of Wayne County, New York. Cornell Univ. Agr. Exp. Sta. Bul. 226:341-345, fig. 86-87.

Attention is given to the economic importance of the canker and to control measures followed by the growers in this section of the country. It is said that very few mature Twenty Ounce trees are not badly cankered, and Esopus suffers seriously.

Whetzel, H. H.

- 1906 The blight canker of apple and pear trees. Western New York Hort. Soc. Proc. 51:36-45.

Compares fire-blight and New York apple-tree cankers.

- 1907 The New York apple tree canker. In Fighting the fungi in their winter quarters. Cornell reading-course for farmers, March, 1907, p. 670-671, fig. 365.

Gives symptoms of canker and measures for its control.

Whetzel, H. H., and Stewart, F. C.

- 1908 New York apple-tree canker. In Insect pests and plant diseases. IV. The control of plant diseases Cornell Univ. Agr. Exp. Sta. Bul. 252:357, fig. 165.

Suggestions for canker control are given.

Wilcox, E. M.

- 1905 Black rot. Also Canker. In Diseases of the apple, cherry, peach, pear, and plum; with methods of treatment. Alabama (Auburn) Agr. Exp. Sta. Bul. 132:89-93, pl. 2, fig. 6.

Notes on symptoms and control of black rot and canker.

Wilcox, E. M., and Stone, R. E.

- 1909 Black rot (*Sphaeropsis Malorum*). In Directions for the control of Nebraska plant diseases. Nebraska Agr. Exp. Sta. Ann. rept. 22:31.

Give schedule for control of canker and black rot.

Wilson, G. W.

- 1913 New York canker. In Notes on three limb diseases of apple. North Carolina Agr. Exp. Sta. Ann. rept. 35:47-49, fig. 1.

Brief summary of history, distribution, importance, and symptoms of the disease. Author states that the fungus may enter the bark under certain conditions, and that it does not travel in the wood.

Wolf, F. A.

- 1910 The prevalence of certain parasitic and saprophytic fungi in orchards as determined by plate cultures. *Plant world* 13: 190-202.

By use of trap cultures the author concludes that at no time during the period in which exposures were made (September to May) were viable spores of *Sphaeropsis Malorum* present in the atmosphere of the orchard.

- 1913 Control of apple black-rot. *Phytopath.* 3: 288-289.

Suggests that apple mummies are a source of the inoculum. Reports that in the South lime-sulfur alone is effective against the disease; bordeaux 4-4-50 also satisfactory. A spraying schedule is given.

